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WATER CONTROL IN THE PEAT SOILS OF FLORIDA

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(Based on experiments conducted under a cooperative agreement between the Agricultural Experiment Station of the University of Florida and the Bureau of Agricultural Engineering of the United States Department of Agriculture.)

Introduction

The area of peat land in Florida has been estimated at approximately 3.5 million acres and about three-fourths of it is in the Everglades. Proper control of water is essential to the conservation of peat soil and successful cultivation of crops.

For the purpose of studying the control of water in Florida peat soils a cooperative agreement was made between the Bureau of Agricultural Engineering, U.S. Department of Agriculture and the Agricultural Experiment Station of the University of Florida. The study under this agreement began in the spring of 1932 and has been continued during the past several years. The headquarters for the investigation has been the Everglades Experiment Station near Belle Glade. Prior to this investigation some data relative to subsidence of peat soils and variation of water tables were obtained by engineers working under the direction of the Division of Drainage of the Bureau of Public Roads, U.S. Department of Agriculture, now the Bureau of Agricultural Engineering.

Some of the most important subjects studied were the fluctuation of ground water tables, the amount and rate of subsidence, rainfall and evaporation, costs of pumping, and the optimum depth of water table for various crops.

From a study of the fluctuations of water tables along particular well lines some data have been obtained on the depths to water table as affected by rainfall, pumping, lake and ditch stages, levees, and prolonged dry periods. The seepage movements of water as affected by the above factors have also been noted. These data are of value in planning pump installations and drainage works and in other problems connected with water control.

The study of the amount and rate of subsidence in peat soils is of great importance in estimating the ultimate useful life of such land, in the planning of drainage works, and in any consideration of means to reduce the rate of subsidence and thus conserve the soil for the longest possible period of use.

Data on rainfall and evaporation is essential to planning pump installations and other drainage works. The distribution of rainfall throughout the year, the intensity of particular storms, and the probable occurrence of storms of different intensities are all matters of much practical interest. The evaporation and transpiration from large areas and from cropped fields are of value in determining the net seepage and considerations of the means of conserving the peat soil not yet cultivated.

Data on the cost of pumping and the amounts pumped from typical areas are of value in the design of pumping plants and in economic studies of the costs of crop production and land use.

Such data as have been collected on the above subjects is presented in this report. In addition a study is now in progress to determine the effect of depth of water table, variation of water table, and spray irrigation on crop response. A series of eight plots each approximately 100 feet by 240 feet are being used in this study, the results of which will be published in a later report.

The accompanying map (fig. 1) shows the general location of the peat lands near the south and east shores of Lake Okeechobee. The area shown is located within the Everglades Drainage District, and nearly all the land now in cultivation is located in the sub-drainage districts shown on this map. The area of peat land now in cultivation in the lake region is approximately 65,000 acres. About one fourth of this is in sugar cane and most of the remainder in truck crops. In the past this area has been exposed to flood hazards due to hurricanes passing over Lake Okeechobee. A levee recently completed now eliminates this danger, and with the improvement of roads and drainage facilities it is probable that the cultivated area will be substantially expanded during the next decade.

Lake Okeechobee

Lake Okeechobee covers an area of approximately 730 square miles. Its shape is roughly that of a circle with a diameter of 30 miles. The lake occupies a shallow depression, the lowest part of which is substantially at sea level. The total tributary drainage area including the lake surface is approximately 5,200 square miles. Of this total the Kissimmee valley accounts for 2,425 square miles.

Before drainage works were constructed the normal lake elevation was approximately 20.5 feet above mean low tide, and there was a substantial overflow along the south shore of the lake into the Everglades. The stages varied from 13.8 to 21.7 feet before the opening of the St. Lucie Canal in 1926. Since that time the range has been from 13.0 to 19.5 feet with the exception of 1932 when a minimum of 11.8 feet was reached due to lowering the lake on account of levee construction.

Since the completion of the St. Lucie outlet it has been the purpose of those in charge of regulation to keep the lake stages as nearly as possible between 14 and 17 feet. With the completion of the Caloosahatchee Canal the combined capacity of the lake outlets will be 7,500 second-feet;

a sufficient amount to lower the lake about one foot from normal level in 30 days. The lake stages have a material effect on the water table in adjacent lands.

Description of Peat Land

The Everglades of southern Florida constitute one of the largest bodies of peat lands in the world. The area covered by this soil is about 2,700,000 acres. It lies in a trough about 40 miles wide by more than 100 miles in length and extends from Lake Okeechobee to the sea. On either side is a low sandy ridge. The slope from north to south is approximately 2 inches per mile. The elevation near Lake Okeechobee is now approximately 16 feet above mean low tide. Prior to drainage the ground surface near the lake was 4 to 5 feet higher but has since been lowered by subsidence due to drainage and cultivation.

The depth of peat deposit varies generally from north to south. Near the lake it is 8 to 12 feet in depth but at the southern end of the Glades the rock is very close to the surface. The peat deposit for the most part rests on a bed of coral or oolithic limestone but a minor portion is underlaid with sand. This rock and sand is quite porous permitting a rather free movement of seepage water.

The peat deposits of the Everglades have been formed mainly through the partial decomposition of saw grass. They are principally composed of organic materials with a minor amount of inorganic matter varying with the special conditions existing during the period of formation. Bulletin 190 of the Florida Agricultural Experiment Station, describes these soils as follows: "The accumulation of plant residues under conditions of excessive moisture usually constitutes peat soils. Under such conditions the anaerobicity, or lack of air, largely prevents the decomposition of the freshly fallen material beyond a certain stage; hence the accumulation of such organic deposits from century to century."

The peat lands of northern Everglades are commonly divided into three classes: namely, the "custard apple" or plastic muck, the intermediate or "elderberry and weed land," and the saw-grass peat.

The "custard apple" soil includes about 20,000 acres lying in a zone of from $\frac{1}{2}$ to $2\frac{1}{2}$ miles wide, along the east and south shores of Lake Okeechobee. The surface soil to a depth of 6 inches or more is composed of a heavy plastic material containing 40 percent to 50 percent of inorganic matter. This soil was largely formed by the sedimentary deposits of succulent water plants. The mineral content is due largely to silt deposits from lake overflow.

Between the "custard apple" or plastic muck soil and the saw-grass peat is the intermediate type commonly called "elderberry and weed land." The top soil is of a fibrous material more decomposed by weathering than the typical saw-grass soil. The subsoil, though principally composed of the brown fibrous layers of saw-grass peat also contains layers of the plastic, sedimentary muck. The area of intermediate type is not well defined as it merges into the true saw-grass peat.

The typical saw-grass peat covers by far the greater portion of the Everglades. Until exposed to weathering this peat is of a brown fibrous nature. The partially decayed roots of the saw grass can readily be distinguished. The mineral content averages about 10 percent of the oven dry weight, and the dry soil is much lighter than the "custard apple" or plastic muck. A number of soil samples to a depth of 3 feet, taken from cultivated areas of both "custard apple" and saw-grass peat, showed the dry weight of the former to be about double that of the latter.

In December 1935 soil samples were taken from 16 locations within a 10-acre field at the Everglades Experiment Station. At a depth of about 16 inches to 18 inches is a thin layer of plastic muck but the remainder of the soil is typical saw-grass peat. The field had received some drainage about 20 years earlier when the Hillsboro Canal was completed but the drainage was greatly improved with the installation of pumps by the Experiment Station in 1925. The field has been cultivated only during the last few years. The average oven dry weights and ash weights per cubic foot of field sample are shown in table 1.

Table 1.- Oven-dry Weight and Ash Weight of Soils at Everglades Experiment Station

Depth of sample	Oven-dry weight per cubic foot	Ash weight per cubic foot	Ash to oven dry weight
Inches	Pounds	Pounds	Percent
0-6	17.5	1.76	10.1
6-12	12.2	1.27	10.4
12-18	11.4	2.00	17.5
18-24	9.5	1.14	12.0
24-30	8.1	.68	8.4
30-36	7.5	.62	8.3
36-42	7.8	.70	9.0
42-48	7.7	.73	9.5
Average	10.2	1.11	10.7

The large ash weight for the 12 to 18 inch depth is due to the thin layer of plastic muck. If the samples for this depth are omitted the remaining samples of typical saw-grass peat show an ash weight of 10 percent of the oven dried weight. The data further show that the dry weight of the top 6 inches of soil is approximately double that at a depth of 18 to 30 inches, showing the effect of compaction, weathering and oxidation as the saw-grass soil is slowly changed into a condition approaching a true muck. These results are based on 64 field samples taken with a brass cylinder 6 inches long and 4 inches in diameter.

A small number of samples taken to depths of 3 feet in typical "custard apple" muck near Lake Okeechobee, showed average oven dry weights of 21 to 24 pounds per cubic foot of field sample and an ash weight of 12 to 15 pounds per cubic foot. The ratio of ash to oven dry weight varied from 52 to 57 percent. It is thus evident that the mineral content of plastic muck far exceeds that of saw-grass peat.

Several tests with saturated samples of saw-grass peat showed a weight of approximately 64 pounds per cubic foot or slightly heavier than water. More extended tests may show a substantial variation from this figure.

In this report the work "peat" will be used as a general term to cover all types of the organic soils constituting the Florida Everglades. The three types will be distinguished as needed by the terms "custard apple or plastic muck"; "elderberry and weed land"; and "saw-grass peat." The term "muck" has been commonly applied to all variations of these peat soils but strickly speaking "muck" is the residue developed from decomposition of the raw plant remains of peat soils following drainage and cultivation.

Fluctuation of Ground Water Tables

In the spring of 1932 a number of well lines were established to record the rise and fall of the ground water elevations in certain areas near Lake Okeechobee. The locations of these lines are shown on figure 1. A chart for each line shows the fluctuation of the water level in a typical well over a period of several years. The rainfall, lake or canal levels and other data affecting the ground water levels are also shown. A profile for each of the lines shows some typical ground water curves, the depth of peat, and the distance between wells.

Charts and profiles have been prepared for 12 lines designated as lines, A, B, C, D, E, G, M, O, Q, R, S, T, and U. Special location maps have also been prepared showing the relation of the lines to section corners, ditches and roads so that the lines can be relocated when desired. A short discussion of the water table variations along the several lines has also been prepared.

However in this report the data for only four of the most important lines will be presented and the fluctuation of water tables due to rainfall, pumping, lake, and ditch stages will be discussed. Those interested in securing the charts, profiles, and a short discussion of the remaining lines may have these by writing the Bureau of Agricultural Engineering at Washington, D.C.

In order to secure an accurate record of the water table fluctuations, a line of wells was established along each line. Iron rods were driven into the rock at each of the wells and their elevations determined as reference points. The plane of reference for all well lines is mean low tide at Punta Rassa, Florida. The depths to rock, marl, or sand were determined by sounding with an iron rod at each well. The wells were usually read once a week, and on particular lines automatic water stage recorders were later installed, thus providing a daily record of water stages in typical wells.

Well Line B

Line B (fig. 1) crosses the Hillsboro Canal at a point about 9 miles southeast of Belle Glade. It extends back from the canal approximately a half mile to either side. On the west side of the canal is a levee and a hard surfaced road while the water on the east side can readily reach the canal.

The soil is a saw-grass peat underlaid with porous limestone at an average depth of 7.6 feet. The surface slope is nearly flat near the ends of the line but increases towards the canal. Due to drainage and subsidence large cracks have formed and these are most noticeable near the canal. The vegetation near the canal is weeds with saw-grass further back. The wells on both sections of the line were read up to February, 1933. As the ground water profiles were substantially the same for both sections of the line, only the west section was read after that date. All regular readings were discontinued in August, 1934.

Figure 2,A shows the variations in water levels in two typical wells on the west side of the canal. The stages in the Hillsboro canal and the rainfall at Shawano, about 4 miles below the well line, are also shown. The well readings are connected by a broken line. The Hillsboro stages are taken from the daily readings at Shawano adjusted to agree with the weekly readings at the well line. Figure 2,B shows some typical ground water profiles along this line.

One of the objects in establishing this line was to determine the effect of a substantial levee on the seepage gradient. An examination of Figure 2,B indicates that the ground water profiles are substantially the same on the levee side as on the open side of the canal, and that the levee therefore has little effect on the seepage movement of the water.

The lowest stages reached during the period of the record was in May, 1932. This was at a time when Lake Okeechobee was at a record low stage due to levee construction but it is doubtful if the lake was the occasion for the low water along this line. The previous six-month period had been very dry and the rainfall during the two preceding years had been subnormal. The ground water storage was thus depleted; hence the low well stages.

A comparison of the stages in well 13 with those of the lake shows that the lake was lower than the well stages almost continuously from April, 1932 to September, 1933. From December 1933 until August, 1934 the lake was at the higher level. Since the winter and spring of 1932 and the winter of 1933 were quite dry it seems possible that a portion of the seepage water may be artesian water originating in some higher area north of Lake Okeechobee.

Well Line D

Line D (fig. 1) begins at the old levee on the south side of Lake Okeechobee and extends southward across the east portion of Sections 5 and 8-44-36 to the Florida East Coast Railroad. The line is about a quarter mile west of the east line of these sections. A road ditch along the north line of section 8 provides some surface drainage to the land. This line is located in the South Shore Drainage District which has no permanent pump installations. The highest portion of the line is in section 5 north of highway 25. This high ground was doubtless the old rim of the lake.

The soil is "custard apple" or plastic muck underlaid with limestone at an average depth of 7.7 feet. The oven-dry weight of the top foot of soil near well 8 was 35.0 pounds per cubic foot of field sample and the ash weight was 22.2 pounds. The corresponding weights near well 27 are 32.3 and 20.5 pounds respectively. During the period of the record the land has been used for truck crops. The surface drainage is fair but could be improved by installing better ditches and a district pumping unit.

The well records on this line extend from May, 1932 to January, 1936. Automatic gages were installed at wells 8 and 27 in July, 1934. Previous to this time readings were made about once a week.

Figure 3,A shows the variations in water tables in two typical wells and the stages of Lake Okeechobee for the years 1932 through 1934. The rainfall shown is the average of that at South Bay and at Lake Harbor. The lowest stage in well 8 occurred in May, 1932 at a time when the lake was held at an extremely low level on account of the construction of the new lake levee At that time the water table was 4.7 feet below the surface. The stages in well 8 are nearly always above the lake during the four rainy months from June to September, and during the dry months they are usually a half foot lower than the lake. The lake has a marked effect on the stages in this well.

Well 27 is located nearly a mile south of well 8 and near the ends of long dry spells it is often as much as 2 feet or more lower than well 8. When the lake is above a 15.5 foot stage it appears that the seepage gradient almost always slopes to the south. Below this stage the slope is sometimes reversed during the wet months.

During the winter and spring the stage in well 27 is commonly from 2 to 2.5 feet below the lake and has reached an extreme difference of nearly 3 feet. The extreme low stage of May, 1932 was preceded by nearly a year of very low lake levels and by more than a year of subnormal rainfall. With the lake at about a 16-foot stage the seepage gradient appears to increase during the dry months until it reaches a slope of from 2 to 2.5 feet per mile along this well line.

The new lake levee is located about a quarter mile north of the end of line D. A fire trench and a seepage trench were first excavated to the rock or shell beneath the soil and refilled with marl and shell. The levee was completed across the end of this line during the summer of 1935. The subsequent record on this line will give some indication of the effect of these fills on the seepage gradient. As far as the present data go these changes have had no substantial effect on the water table along this line.

Figure 3,B shows the drop in ground water levels during a dry period subsequent to heavy rains in early November, 1932. The profile for November 11, shows the water table sloping in both directions from about the middle of the line. By December 31, it was practically level and thereafter sloped entirely to the south. The road ditch at highway 25 caused a slight depression in the gradient lines.

Unit 3 of the South Florida Conservancy District is located south of the railroad at the end of line D. Nearly all the pumping operations take place during the summer and fall months. It is therefore not probable that the low water tables during the winter and spring months on line D are substantially affected by the conditions in this pumping unit.

Well Line G

Line G (fig. 1) is located in Section 3,T.44, R.37, on land of the Everglades Experiment Station near Belle Glade. It begins at a point on the Hillsboro Canal about 860 feet northwest of the pumping plant and runs in a southwesterly direction at right angles to the canal through land used for experimental plots. The area has been underdrained with mole lines 30 inches deep and 15 feet apart. These mole lines connect farm ditches 240 feet apart.

The soil is saw-grass peat underlaid with porous limestone at an average depth of 7 feet. Soil samples taken near well 10 to a depth of 3 feet showed an average oven-dry weight of 12.2 pounds per cubic foot of field sample, and an ash weight of 1.48 pounds. The land has been in cultivation about 12 years and as a result of weathering and compacting the top foot of soil has an oven-dry weight about twice as great as that at a depth of from 2 to 3 feet. At a depth of 1.5 to 2.0 feet is a thin layer of plastic muck. The area near this line has had good drainage as the pumping plant is of large capacity and is operated as needed during the entire year.

The period of well records covered in this report includes the years 1932, 1933, and 1934. For some years prior to this time a record was kept by the Everglades Experiment Station and since 1934 the record of the water table in this section of the Experimental farm has been continued along a line parallel to and 615 feet east of line G.

Figure 4,A shows the water table variations in a typical well, the stages of the Hillsboro Canal, the days on which the pump was operated and the rainfall. The well readings were made about a week apart. The chart clearly shows that the amount of pumping largely depends on the stage of the Hillsboro Canal. A comparison of the June records for 1933 and 1934 shows much more pumping for the higher stage of the canal although the rainfall for the two periods did not vary much. The October records for 1932 and 1934 also show a similar relation between the canal stages and the periods of pump operation. A rise in the canal stage causes an increase in the rate of seepage into the pumped area. This seepage water apparently moves through the porous rock beneath the soil.

The highest water during the period covered occurred on November 7, 1932, following a record rainfall of 10.9 inches during the previous night. The water covered the ground for more than two days although the pump was operated to maximum capacity. After the water reached the ground level it required 24 hours of additional pumping to reduce the water table 0.8 foot in well 7. This well is midway between mole lines 15 feet apart. A well similarly located as to ditches and 615 feet east of well 7, but in undrained ground took three days to drop the same amount. This comparison shows the value of mole lines in soil having ditches not over 240 feet apart. As the major portion of the roots of truck crops are in the top foot of soil, the value of the mole lines in reestablishing normal air conditions is evident.

Figure 4,B shows some typical water table profiles for line G. The water table rises very sharply from the ditch to a point 15 or 20 feet back. The more rapid drop in water levels in those sections of the line near the Hillsboro Canal is clearly evident in the November, 1932, profiles. This is doubtless due to the more effective drainage provided by the mole lines in the portion near the canal.

Well Line S

Line S (fig. 1) is located in Section 34-41-37, and also in the north unit of the Pelican Lake Drainage District. It begins at the West Palm Beach Canal and extends in a northeasterly direction about 3,000 feet. Lake Okeechobee is about 2/3 mile away.

The soil is of the intermediate type of "elder and weed" land and is underlain with limestone at depths varying from 9.4 to 12.8 feet. Soil samples taken near well 18, to a depth of 3 feet, showed an average oven dry weight of 15.4 pounds per cubic foot of field sample, and an ash weight of 4.79 pounds. The land is used to grow sugar cane. The period of records along this line extends from May, 1932 to January, 1936.

Figure 5,A shows the water table fluctuations in a typical well, the stages in the West Palm Beach Canal, the rainfall at Azucar, and the days on which the district pumps were operated. In July, 1934 an automatic gage was installed at well 18. The sudden changes in the West Palm Beach Canal at times of little or no rainfall are due to regulation of the locks near the lake. Figure 5,B shows some water table profiles along this line.

The highest water during the period of the record occurred in November, 1932, following the record rain of November 7. The district levees broke shortly after this rain, flooding the ground to a depth of over 3 feet. The water remained above the surface for nearly a month. The lowest stage was in August, 1935 when the water table was 3.5 feet below the surface. The West Palm Beach Canal at this time was also exceptionally low.

Amount of pumping required depends very materially on the stage of the West Palm Beach Canal. The water table in the land outside the levee on the east side of the Pelican Lake District also affects the amount of pumping. The water there is often above the ground due to run-off from higher land to the northeast.

Figure 5,A shows that the rainfall was almost the same for both October, 1932 and October 1933, but that the canal stage was approximately 3 feet higher in the later period. The pumps operated a total of 701 pump-hours in October, 1933 and only 62 pump-hours in October, 1932. The records for August, 1934 and August, 1935 also show the large variations in pumping due to the stages in the West Palm Beach Canal.

As shown in Figure 5,B, line S is divided into three sections by field ditches. The general slope of the seepage gradient is nearly always towards the West Palm Beach Canal. The dotted line in the profiles shows the gradient sloping away from the canal and higher in the ditches than in the fields. It is only during dry periods, after pumping operations have ceased, that the water table is lower in the fields than in the ditches. This condition is probably caused by the fact that evaporation and transpiration losses exceed the seepage inflow. As an inch of water will saturate about 6 inches of soil, the evaporation losses will cause a greater drop in the soil than in the ditches. Unless rains interfere the drop in the soil water continues to exceed that in the ditches until there is a balance between the seepage inflow and evaporation losses.

The field ditches divide line S into two sections of about 800 feet each and one of 1,250 feet. The well records show that the water drops somewhat more rapidly in the shorter sections. When the water table is high continuous pumping usually produces a drop of a foot in 8 to 12 days--the rate of fall depending somewhat on the stage of the West Palm Beach Canal.

Summary of Water Table Study

As the water table in the peat soils near Lake Okeechobee is affected to some extent by rainfall, pumping, lake and canal stages, it is difficult to draw general conclusions from a study of fluctuations along well lines. In planning drainage improvements the special conditions around an area should be carefully considered. There are, however, some relations of the seepage movements which appear to be confirmed by this study of particular well lines.

The major portion of the seepage water appears to move through the porous rock or sand beneath the peat rather than through the soil above. Where a block of land is surrounded by a high water table and the ditches within the area are held at a low stage by pumps, the soil water will remain at a higher stage than the ditches over extended periods of dry weather, thus indicating the upward movement of the seepage water due to the pressure from a higher water table in the lands outside the levees. The observations of ditch and well levels on experimental water table plots at the Everglades Experiment Station and also along certain field lines support this conclusion.

It also seems evident that there is considerable resistance to the horizontal seepage movement through the peat. The water table profiles for high stages in the wells are quite flat along the major portion of the distance betweem ditches but near the ends they slope down rather sharply to the ditch levels. If the soil were mostly sand or other porous material, the end slopes would be much more gradual.

These profiles also indicate that it is not advisable to place farm ditches more than an eighth of a mile apart and the area between ditches should be mole drained. The data for well line G at the Experiment Station, indicates that following rains the water table will drop considerably faster in mole-drained soil than in similar sections of soil without mole drains. These mole drains are commonly spaced 12 to 15 feet apart and 30 inches deep but in saw-grass soil it appears that heavy farm machinery may close the lines and that lines at greater depth would be more durable.

A substantial levee built over peat soil evidently has little or no effect on the seepage gradient. A seepage ditch along the inner toe of a levee depresses the seepage gradient when the water is higher on the outside than within. It is better, however, to use a narrow seepage ditch as a wide ditch dug to rock may allow a levee to slide when there is a high head without.

A study of the automatic gage records on a number of well lines indicate that a heavy rain may raise the water table from 5.5 to 7 times the depth of precipitation. An experiment with peat soil in a large steel tank showed similar results; an addition of 3 inches of water showed a rise of 18 inches or a ratio of 6 to 1. However, as this saturation takes place slowly it is not advisable to give much weight to such ground storage in determining the capacity of a pumping plant.

The data for lines E, D, T, and U give some indication of the effect of Lake Okeechobee on the water table in the adjacent land. The extent of this effect can be only roughly defined. However, the available data indicate that the lake stages have a noticeable effect to a distance of about a mile back from the edge of the lake and a very substantial effect to a distance of a half mile. The most satisfactory lake level is approximately 16 feet. A variation of 15 to 17 feet in lake stage would be a very desirable range from an agricultural standpoint, but due to the occasional occurrence of extreme dry years and extreme wet years this range could not be maintained at all times. However, with the improved lake outlet it is probable that the variation can now be held between 14 and 18 feet.

Rainfall in the Northern Everglades

On the peat lands surrounding Lake Okeechobee there are four rainfall stations now in operation with records of more than 10 years. These four stations are located at Canal Point, Moore Haven, Everglades Experiment Station and the Shawano plantation. Data from the four stations are here presented to show the variation in rainfall on the peat lands of the upper Everglades. There was also a record at Ritta from 1914 to 1930, inclusive, but this station was discontinued at the end of that period.

The station at Canal Point is maintained by the Cane Experiment Station of the U.S. Department of Agriculture; that at Moore Haven by the U.S. Weather Bureau; that at Everglades Experiment Station by the Agricultural Experiment Station of the University of Florida, and that at Shawano by the Brown Company. Tables 2, 3, 4 and 5, show the monthly and annual rainfall for the four stations above mentioned. The maximum, minimum and average monthly and annual rainfalls are also shown.

Table 2.- Rainfall in Inches at Canal Point

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1923	1.53	.14	.34	1.55	7.06	6.62	8.48	9.95	8.31	3.17	.43	.45	48.03
1924	3.00	2.23	3.71	2.17	2.27	4.84	11.08	1.85	10.97	18.14	.89	.15	61.30
1925	4.46	2.24	2.46	3.50	9.73	8.62	8.47	7.12	4.09	2.25	1.67	1.99	56.60
1926	6.19	2.25	1.63	3.33	1.54	8.62	7.45	5.72	14.82	1.24	.72	.10	53.61
1927	.33	1.80	2.37	1.08	1.54	6.31	7.32	8.14	3.31	3.35	.49	.40	36.44
1928	.19	1.38	3.48	1.72	3.10	5.42	14.57	14.13	16.45	.77	1.24	.20	62.65
1929	1.34	.07	.60	2.32	5.43	11.74	11.26	6.31	10.70	3.08	.69	1.08	54.62
1930	2.54	3.03	4.32	9.25	6.10	16.96	4.08	3.07	5.36	5.14	.67	2.77	63.29
1931	2.05	.91	4.27	5.71	3.05	.49	3.33	4.67	5.64	4.43	.70	4.62	39.87
1932	.26	2.38	.87	2.67	3.49	11.26	4.91	9.91	2.40	4.51	25.09	.16	67.91
1933	1.54	.35	4.73	6.42	1.31	7.62	14.02	8.51	8.16	4.36	1.84	.09	58.95
1934	.25	5.36	2.77	7.64	6.27	7.96	5.20	8.14	11.69	1/ 2.40	1/ .55	1/ .58	58.81
1935	.16	2.81	.17	5.45	.76	6.11	3.98	3.62	11.90	4.44	.57	1.22	41.19
Ave.	1.83	1.92	2.44	4.06	3.97	7.89	8.01	7.01	8.75	4.41	2.73	1.06	54.10
Max.	6.19	5.36	4.73	9.25	9.73	16.96	14.57	14.13	18.45	18.14	25.09	4.62	67.91
Min.	.16	.07	.17	1.08	.76	.49	3.33	1.85	2.40	.77	.43	.09	36.44

1/ Rainfall for month estimated from records of nearby stations.

Table 3.- Rainfall in inches at Moore Haven

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1918	---	---	---	2.05	.35	2.55	2.87	6.94	10.83	2.72	.98	.73	---
1919	1.25	3.70	2.83	.62	6.70	10.59	6.88	4.12	2.78	.90	4.86	1.15	46.38
1920	2.10	2.59	.53	5.13	3.05	6.84	15.21	4.51	3.18	2.72	4.54	.63	51.03
1921	.45	1/1.99	1/.84	1/.66	1/5.86	1/2.16	1/5.11	1/3.65	1/2.16	8.35	2.19	.25	33.67
1922	.70	1.10	.74	.46	5.14	9.82	7.63	6.72	14.93	10.70	1.56	.89	60.39
1923	.32	.49	.62	3.55	11.70	12.52	7.54	10.04	4.23	1.39	.21	.28	52.89
1924	3.05	1.75	3.38	3.55	1.21	8.86	11.77	4.76	8.41	13.39	.30	.09	60.52
1925	2.21	1.88	2.04	3.92	6.43	8.69	4.68	9.83	1.08	1.54	.93	2.83	46.06
1926	3.49	1.19	1.12	3.82	2.13	15.05	11.24	6.24	1/8.90	1/1.93	1/1.74	.10	56.95
1927	.11	2.09	1.70	2.02	1.94	10.79	5.79	8.61	6.99	4.12	.38	.39	44.93
1928	.42	2.31	2.46	1.52	4.19	8.12	5.43	11.82	14.60	.47	.97	.31	52.62
1929	.82	.14	.52	1.55	2.73	9.35	8.44	4.93	13.45	1.71	1.27	1.39	46.30
1930	.49	3.23	4.76	4.12	11.33	17.85	4.72	11.61	11.26	6.33	.45	2.33	78.48
1931	2.58	.76	5.90	3.44	1.59	1.20	2.68	10.34	5.06	1.94	.08	.35	35.92
1932	1.97	3.13	2.87	1.76	6.05	4.96	6.25	15.71	5.99	2.93	3.28	.07	54.97
1933	1.65	.19	3.88	6.92	3.89	4.66	6.36	5.77	2.75	5.18	.92	.28	41.45
1934	1.33	2.89	2.73	2.22	6.43	4.36	8.48	6.20	4.18	5.54	3.58	.26	48.20
1935	.52	1.00	.03	5.18	3.57	5.84	5.09	5.50	9.53	1.42	1.71	1.48	40.87
Ave.	1.38	1.79	2.17	2.92	4.68	8.01	6.95	7.63	7.24	4.07	1.66	.77	50.10
Max.	3.49	3.70	5.90	6.92	11.70	17.85	15.21	15.71	14.93	13.39	4.86	2.83	78.48
Min.	.11	.14	.03	.46	.35	1.20	2.68	3.65	1.08	.47	.08	.07	33.67

1/ Rainfall for month estimated from records of nearby stations.

Table 4.- Rainfall in Inches at the Everglades Experiment Station

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1924	---	---	---	---	---	---	6.59	3.72	8.49	15.84	.62	.22	---
1925	3.58	2.49	2.37	3.78	9.38	5.61	5.56	12.36	4.17	.49	1.14	2.84	53.77
1926	5.39	.66	1.48	1.81	3.69	9.29	10.87	10.40	13.60	3.58	.91	.55	61.93
1927	.32	2.90	2.18	2.44	3.19	7.08	12.77	11.45	6.41	4.50	.42	.42	54.08
1928	.31	1.66	3.83	1.78	2.61	9.20	8.25	11.31	19.04	1.46	1.07	.25	60.77
1929	1.20	.49	1.70	2.61	8.92	11.11	7.32	3.79	12.23	4.71	4.13	.92	59.13
1930	1.92	2.40	6.32	6.03	4.43	19.61	6.28	3.74	3.58	4.94	.56	3.54	63.35
1931	2.31	1.17	3.93	4.41	3.16	.59	3.05	7.67	10.68	4.16	.51	1.11	42.75
1932	1.72	2.13	1.56	1.54	4.69	16.01	3.93	10.59	7.43	3.68	12.36	.50	66.14
1933	.64	.38	5.42	6.90	4.04	9.51	3.85	12.75	11.89	5.30	4.50	.12	65.30
1934	.14	1.91	7.10	3.11	5.20	10.15	10.09	12.41	7.44	3.22	.65	.82	62.24
1935	.30	1.32	.41	5.32	1.08	8.45	6.37	6.54	10.88	5.71	.36	2.07	48.81
Ave.	1.62	1.59	3.30	3.61	4.58	9.69	7.05	8.89	9.65	4.80	2.27	1.11	58.02
Max.	5.39	2.90	7.10	6.90	9.38	19.61	12.77	12.75	19.04	15.84	12.36	3.54	66.14
Min.	.14	.38	.41	1.54	1.08	.59	3.05	3.72	3.58	.49	.36	.12	42.75

Table 5.- Rainfall in Inches at the Shawano Plantation

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1925	---	---	---	---	---	---	---	7.38	2.42	.63	3.84	1.71	---
1926	4.86	1.29	1.48	3.24	3.41	5.85	5.64	12.02	6.64	4.58	1.45	.43	50.89
1927	.37	1.72	1.82	1.55	3.14	4.94	5.19	8.16	4.91	3.58	.51	.60	36.49
1928	.83	.25	2.18	6.74	4.90	8.16	5.27	14.66	16.48	1.08	1.05	.44	62.04
1929	.46	.78	2.08	2.68	6.18	6.64	7.51	5.66	10.45	6.20	2.92	1.73	53.27
1930	1.33	2.29	5.09	5.36	3.54	9.03	3.20	2.83	6.14	2.47	.96	2.00	44.24
1931	2.61	.98	4.29	5.00	2.63	1.20	4.65	8.32	9.31	5.29	.96	.54	45.78
1932	2.10	.99	2.28	.99	5.02	8.45	2.06	10.83	4.00	4.11	5.64	.15	46.62
1933	1.02	.19	3.11	4.51	2.01	6.52	10.36	8.59	8.03	11.30	3.17	.30	59.11
1934	.56	1.09	4.38	3.15	6.41	5.07	9.77	9.85	5.14	2.01	.54	2.13	50.10
1935	.61	.78	.64	7.28	1.59	10.13	4.13	11.36	12.81	6.11	.61	3.01	59.06
Ave.	1.48	1.04	2.74	4.05	3.88	6.60	5.78	9.06	7.85	4.31	1.97	1.19	50.76
Max.	4.86	2.29	5.09	7.28	6.41	10.13	10.66	14.66	16.48	11.30	5.64	3.01	62.04
Min.	.37	.19	.64	.99	1.59	1.20	2.06	2.83	2.42	.63	.51	.15	36.49

The average rainfall for the four month's period from June to September at each of the four stations is approximately 60 percent of the mean annual precipitation. This is the period of greatest rainfall. The four month's period of least rainfall is from November to February. During this time the average precipitation at the several stations varied from 11 percent to 14 percent of the annual mean. Of the four stations the greatest mean annual rainfall is that at the Everglades Experiment Station and the least is that at Moore Haven. The records at these stations vary by nearly 8 inches.

Two of the longest records at stations in South Florida are those at Ft. Myers and Miami. A 67-year record at Ft. Myers, including 1935, shows a mean annual precipitation of 51.87 inches, a maximum of 82.64 inches, and a minimum of 32.85 inches. At Miami a 48-year record shows an annual mean of 59.51 inches, a maximum of 89.07 inches and a minimum of 33.69 inches.

Table 6 shows the record of excessive precipitations at the Everglades Experiment Station for the year 1935, as determined from the charts of a weighing rain gage. No very excessive storms occurred. The greatest rate for 1 hour was 2.07 inches, and that for 2 hours was 2.73 inches. The U.S. Weather Bureau record for Miami shows a maximum rainfall of 3.50 inches in 1 hour and 6.11 inches in 2 hours.

One of the greatest 24-hour rainfalls ever recorded in Florida occurred at Canal Point in November, 1932. The record at the U.S. Cane Experiment Station showed 21.92 inches. By far the greater portion of the rain fell from 11 p.m. November 6, to 7 a.m. November 7. During the preceding day 1.90 inches was recorded making a total of 23.82 inches for 48 hours. Other rain gages within a few miles of this station showed amounts varying from 19.0 to 21.2 inches in 24 hours. The greatest 24-hour rainfall recorded at the Everglades Experiment Station also fell during this storm. The precipitation was 10.90 inches and almost the entire amount fell from 11 p.m. November 6, to 7 a.m. November 7. The greatest 24-hour rainfall recorded within the state, 23.22 inches, occurred at New Smyrna in October, 1924.

Table 7 shows the number of rains of 2 inches or more which have occurred in 24 hours at the Everglades Experiment Station, at Moore Haven, and at Canal Point during the periods of record. The number of rains are shown according to size groups as indicated in the first column.

Of the 49 rains of 2 inches or more at the Everglades Experiment Station approximately 63 percent were from 2 to 3 inches in amount and 57 percent occurred during the four wet months of June to September. At Moore Haven 75 percent of the 63 rains shown were in the 2- to 3-inch group and 67 percent of the 63 rains occurred from June to September, inclusive. At Canal Point 75 percent of the 55 rains were in the 2- to 3-inch group and 62 percent of the 55 rains occurred from June to September, inclusive. The records of the three stations indicate that only a few rains of 4 inches or more have occurred during the farming season of October to May, inclusive.

Table 6.- Excessive Precipitation at Everglades Experiment Station for Year 1935

Date	Accumulated amounts of rainfall (in inches) during periods								Maximum amount in inches	
	1 hours	2 hours	3 hours	4 hours	5 hours	6 hours	7 hours	8 hours	1 hour	2 hours
April 7, 1935	1.40	1.44	1.53	---	---	---	---	---	1.40	1.44
April 26, 1935	.94	1.02	---	---	---	---	---	---	.94	1.02
June 25, 1935	.91	2.98	3.64	3.72	---	---	---	---	2.07	2.73
July 7, 1935	1.41	1.49	1.54	---	---	---	---	---	---	---
July 14, 1935	.89	1.01	---	---	---	---	---	---	---	---
August 9, 1935	.56	1.95	1.97	1.99	---	---	---	---	1.72	1.95
August 12, 1935	1.18	1.24	1.27	---	---	---	---	---	---	---
September 4, 1935	(.48	.62	.82	.99	1.07	1.23	1.37	1.41	.48	.62
	(1.44	1.44	1.52	1.60	1.60	1.64	1.70	1.74	---	---
	(1.77	1.77	1.78	1.82	---	---	---	---	---	---
September 22, 1935	.84	.84	.88	1.06	1.13	---	---	---	.84	---
October 8, 1935	1.11	1.23	---	---	---	---	---	---	1.11	1.23
December 13, 1935	.92	1.41	1.47	1.48	---	---	---	---	.92	1.41

NOTE:- Rains of less than 1-inch in eight hours are not shown. Tabulations of rains of more than eight hours are shown in two or more lines connected by brackets. In such cases each amount in the second line includes the total for the eight hour period in the line above.

Table 7.- Rains of 2 Inches or More on the Muck Area Near Lake Okeechobee

Rain Inches	January	February	March	April	May	June	July	August	September	October	November	December
				Everglades Experiment Station, 1925 to 1935, inclusive								
2 - 3	1	-	3	5	3	6	2	5	3	2	1	-
3 - 4	-	-	-	-	-	4	1	1	2	2	1	-
4 - 5	-	-	1	-	-	-	-	-	3	1	-	-
5 - 6	-	-	-	-	-	-	-	-	-	-	-	-
8 - 12	-	-	-	-	-	-	-	-	1	-	1	-
				Moore Haven, 1918 to 1935, inclusive (See note)								
2 - 3	-	1	1	3	3	10	5	6	9	6	3	-
3 - 4	-	-	-	-	-	2	2	4	2	1	1	-
4 - 5	-	-	-	-	-	1	-	-	1	1	-	-
5 - 6	-	-	-	-	1	-	-	-	-	-	-	-
				U.S. Cane Breeding Station, Canal Point, 1923 to 1935, inclusive								
2 - 3	2	2	1	6	2	2	6	5	13	2	-	-
3 - 4	-	-	-	-	1	3	-	-	-	1	-	-
4 - 5	-	-	-	-	-	1	-	-	2	2	-	-
5 - 6	-	-	-	1	-	-	-	1	1	-	-	-
6 - 7	-	-	-	-	-	-	-	-	-	-	-	-
7 - 8	-	-	-	-	-	-	-	-	-	-	-	-
8 - 22	-	-	-	-	-	-	-	-	-	-	1	-

NOTE: There was no record at Moore Haven from February to September 1921 and from September to November 1926.

Evaporation

During the years 1934 and 1935 evaporation records were kept for several large steel tanks and a standard U.S. Weather Bureau open pan located at the Everglades Experiment Station at Belle Glade. The purpose was to determine the evaporation and transpiration from cane and other crops on peat soil.

The large steel tanks were 4 feet by 12 feet in area by 4 feet deep, and are set in the ground to a depth of approximately 3.5 feet. The bottoms of the tanks were first covered with a 3-inch layer of crushed rock about 1 inch in size so as to allow the water table to more readily equalize when water is added or withdrawn. The soil was placed in layers to an elevation about 6 inches below the tops of the tanks. The water in the tanks was kept at a near constant depth by adding or withdrawing water as needed, using a 2-inch bilge pump for this purpose. The water added or withdrawn was measured in small tanks of such size that an inch over the large tanks was equivalent in volume to a foot in the smaller tanks. The rainfall was measured in a standard rain gage placed nearby. The wind movement shown in total miles per month was recorded on the top of a two-story building about 1,000 feet from the tanks. The crops planted in the tanks were surrounded by the same crops planted around the outside to protect the tank growth from an excessive exposure to wind and sunlight and thus approximate field conditions. The depth of water maintained in 1934 was about the same as that on the Experiment Station farm. The lesser depth during 1935 was due mainly to subsidence of the soil in the tanks.

Tank 1 was planted to a large barrel cane of the P.O.J. 2725 type on February 1, 1934, and tank 2 was planted on the same date to a medium barrel cane of the Co.281 type. Both canes were cut December 13, 1934 following a hard freeze on December 12. The evaporation and transpiration from tank 1, was 51.40 inches (see table 8) and the cane produced at the rate of 46.4 tons per acre. The evaporation and transpiration from tank 2 was 49.32 inches and the cane produced at the rate of 33.0 tons per acre. Tank 3, containing bare soil without shade, had an evaporation of 42.65 inches for the year. The evaporation from the standard U.S. Weather Bureau open pan was 65.27 inches for the year. From experiments in the arid west it has been estimated that evaporation from a reservoir or other large body of open water is 68 to 70 percent of that from a standard open pan. It is probable that this percentage will closely apply to Everglades conditions. The rainfall for the year 1934 was 62.24 inches.

The cane growth during the year 1935 was retarded by wire worms. Tank 2 was replanted on April 15, because of wire worm damage but the stand of cane remained poor. An attempt to kill the wire worms by flooding followed by introduction of tear gas was unsuccessful. The cane growth was stopped by a killing frost on December 1, and was harvested on January 14, 1936.

The evaporation and transpiration from tank 1 was 46.51 inches (see table 9) and the cane produced at the rate of 42.0 tons of mill cane per acre. The evaporation and transpiration from tank 2 was 46.55 inches and the cane produced at the rate of 28.6 tons of mill cane per acre. The

Table 8.- Evaporation and Transpiration from Tanks and Open Pan for Year 1934, Everglades Experiment Station, Belle Glade, Florida

Month	Wind movement	Average depth to water	Evaporation and Transpiration in Inches: Bare No.3 Soil Tank, Average per day	Bare No.3 Soil Tank, Total	No. 1 Cane Tank, Average per day	No. 1 Cane Tank, Total	No. 2 Cane Tank, Average per day	No. 2 Cane Tank, Total	Open Pan, Average per day	Open Pan, Total	Rainfall	Mean Temperature
	Miles	Feet	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	°F.
January	4,600	2.05	0.077	2.39	0.063	1.95	0.076	2.36	0.117	3.63	0.14	63.8
February	5,070	1.94	.102	2.86	.094	1/ 2.63	.095	1/ 2.66	.132	3.69	1.91	62.3
March	5,650	1.87	.109	3.38	.094	2.91	.094	2.91	.179	5.56	7.10	66.4
April	4,950	1.61	.154	4.62	.154	4.62	.147	4.41	.232	6.96	3.11	70.2
May	4,100	1.76	.128	3.97	.118	3.66	.129	4.00	.206	6.40	[illegible]	75.3
June	3,860	1.37	.153	4.59	.179	5.37	.176	5.28	.206	6.19	10.15	78.5
July	3,330	1.66	.150	4.65	.236	7.32	.213	6.60	.230	7.12	10.09	79.2
August	3,410	1.35	.153	4.74	.210	6.51	.177	5.49	.216	6.70	12.41	80.0
September	3,540	1.67	.123	3.69	.189	5.67	.172	5.16	.192	5.77	7.44	79.6
October	3,980	1.93	.110	3.41	.181	5.61	.171	5.30	.185	5.73	3.22	76.1
November	4,250	1.99	.077	2.31	.116	3.48	.119	3.57	.134	4.03	.65	68.0
December	4,220	1.96	.066	2.05	.054	1/ 1.67	.051	1/ 1.58	.115	3.49	.82	63.8
Year	50,960	1.76	.117	42.65	.141	51.40	.135	49.32	.179	65.27	52.24	71.9

1/ Cane was planted February 1 and cut December 13 on account of freeze. Division of evaporation into months is approximate due to storage of water in the soil following rains.

Table 9.- Evaporation and Transpiration from Tanks and Open Pan for Year 1935
Everglades Experiment Station, Belle Glade, Florida

Month	Wind movement	Average depth to water	Cane No. 1 Average per day	Cane No. 1 Total	Cane No. 2 Average per day	Cane No. 2 Total	Bare Soil No.3 Average per day	Bare Soil No.3 Total	Alfalfa No.4 Average per day	Alfalfa No.4 Total	Open Pan Average per day	Open Pan Total	Rainfall	Mean temperature
	Miles	Feet	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	°F.
January	5,179	1.80	0.030	0.93	0.028	0.87	0.067	2.08	0,056	1.74	0.123	3.81	0.30	63.4
February	4,143	1.78	.063	1.76	.058	1.62	.080	2.24	.088	2.46	.152	4.25	1.32	63.1
March	5,087	1.79	.064	1.98	.053	1.64	.095	2.94	.072	2.23	.210	6.52	.41	68.8
April	4,434	1.38	.105	3.15	.162	4.86	.127	3.81	.102	3.06	.250	7.50	5.32	71.1
May	4,073	1.82	.095	2.94	.088	2.73	.090	2.79	.136	4.22	.285	8.84	1.08	76.1
June	2,990	1.46	.137	4.11	.138	4.14	.118	3.54	.167	5.01	.218	6.55	8.45	77.3
July	3,851	1.67	.188	5.83	.202	6.26	.134	4.16	.216	6.70	.238	7.38	6.37	79.3
August	2,956	1.55	.211	6.54	.231	7.16	.141	4.37	.235	7.28	.226	7.02	6.54	80.1
September	4,111	1.28	.188	5.64	.176	5.28	.185	5.55	.123	3.69	.185	5.54	10.88	79.1
October	4,898	1.36	.171	5.30	.176	5.46	.123	3.81	.116	3.60	.173	5.37	5.71	75.9
November	4,148	1.82	.175	5.25	.137	4.11	.050	1.50	.083	2.49	.144	4.32	.36	69.0
December	4,820	1.65	.098	3.08	.078	2.42	.078	2.42	.085	2.64	.113	3.50	2.07	56.4
Year	50,690	1.61	.127	46.51	.127	46.55	.107	39.21	.124	45.12	.193	70.60	48.81	71.6

NOTE: Cane tanks were covered with dry cane leaves until January 21, thus reducing the evaporation for a period of 3 weeks. Cane made poor progress on account of wire worms. Top soil was sieved to a depth of 6 inches on April 15, and cane replanted in Tank No.2. Tank No. 2 was flooded on April 1 in an attempt to kill wire worms, and its average water table depth for April was 1.01 feet. Alfalfa was planted on April 15, but a good stand was not secured and only a scattered growth remained in the fall, hence the drop in evaporation. Cane growth was stopped by a killing frost on December 1.

cane from both tanks when reduced to sugar gave a yield of approximately 204 pounds of 96° sugar per ton of mill cane.

Tank 3, contained bare soil partially shaded by cane planted around the tank but the shading was not equivalent to field conditions. The evaporation for the year was 39.21 inches.

Tank 4, was planted to alfalfa on April 15. Prior to that date the soil was substantially bare. The alfalfa at first made good progress but in the early fall it died down and during the remainder of the year provided some shade over the soil but the transpiration was certainly of little consequence. The total amount of evaporation and transpiration was 45.12 inches.

The evaporation from the Standard Weather Bureau open pan was 70.60 inches during the year 1935, and the annual rainfall was 48.81 inches.

An examination of the results for the two years shows that the two cane tanks and bare soil tank all used more water in 1934 than in 1935, while the evaporation from the open pan was greater in 1935 than 1934. One reason for this was the difference in rainfall in the two years. In 1934 rain fell on 141 days and totaled 62.24 inches while in 1935 rain fell on 119 days and totaled 48.81 inches. The greater amount of rainfall in 1934 kept the top soil in these tanks more moist than was the case in 1935, and thus increased the evaporation from the soil. On the other hand the more frequent rains doubtless raised the humidity of the air over the open pan and hence reduced the evaporation from the water surface. Another probable cause for this difference between the two years is the fact that the cane yield was somewhat greater in 1934 than 1935 and the bare tank was partially shaded during the latter year. The mean temperature and the total wind movement was about the same for both years.

Pumping Records

The early drainage of the peat lands around Lake Okeechobee depended on gravity systems discharging into the large outlet canals which were never entirely completed. Due to the flat topography the ditch gradients are commonly only a few inches per mile and the water movement is hence very slow. Also drainage has caused considerable subsidence which interferes with gravity drainage. In order to improve their drainage nearly all the districts have installed large pumps. As most of these pumps are reversible, water as needed may be pumped into the areas served and thus control the water level during dry periods. Most of the pumping plants discharge directly into Lake Okeechobee, but several pump into the large canals and the water from these may run either into the lake or down the canals, depending on the relative lake and ditch stages.

Nearly all the large plants use the screw type pumps of from 30,000 to 60,000 gallons per minute capacity, but more recently a few large vertical turbine pumps of approximately 45,000 gallon capacity

have been installed. The large screw type pumps are driven by heavy duty diesel engines varying from 80 to 180 horsepower each. During the past few years a number of large pumps driven by electric motors have been installed. The largest of these motors is 150 horsepower.

The drainage districts on the peat lands around Lake Okeechobee have installed pumping plants with a total rated horsepower of approximately 5,100. Of this total, electric motors account for 375 horsepower and the balance is supplied by diesel engines. The total discharge capacity of these plants is approximately 3,960 second-feet and the maximum required lift of the pumps is about 8 feet. The average static lift is probably close to 4.5 feet. The area served by pumps within these districts is approximately 100,000 acres, but a considerable portion of this acreage is not yet in cultivation. Nearly all the larger plants have a discharge capacity of approximately 1 inch in 24 hours over the area served but several of the plants have a capacity of 1.5 inches.

Approximately 60 percent of the average annual rainfall near Lake Okeechobee occurs during the four-month period from June to September, inclusive, and by far the greater part of the pumping is done in this period. During dry periods in the winter and spring a small amount of water is occasionally pumped into the districts in order to raise the water table. The total time that the plants operate during a year varies widely due to rainfall and seepage conditions but probably averages about 55 plant days. As one or more pumps in a given plant may be operated during the day a plant day is determined by adding together the total days of operation of each pump during the year and dividing the result by the number of pumps.

Description of Plants

The locations of the pumping plants covered by this investigation are shown on the map (fig. 1). The four large plants located in the Pelican Lake and East Pahokee drainage districts are fairly typical of the larger plants around Lake Okeechobee. They have a discharge capacity of approximately 1 inch in 24 hours over the area served. The pumps are reversible so that they may be used for irrigation when needed. The fuel used is distillate delivered at a cost of 6.5 cents per gallon. The cultivated acreage within the areas served is largely used to grow sugar cane but a substantial amount is given to the production of truck crops. The East Pahokee district still contains a considerable area of unused land. All four plants pump directly into the West Palm Beach Canal and the total amount of pumping is considerably affected by the canal stage. A high canal stage causes increased seepage into the areas pumped. This seepage movement appears to be principally through the porous rock formation beneath the muck. Continued rainy periods sometimes raise the canal to such a stage that the flow is into the lake for a distance 12 miles back. The ditches within the pumped area are usually held at a low stage during the rainy season on account of the probability of heavy storms.

The lateral ditches are located approximately a half mile apart. Due to the flat topography of the land the ditch velocities are low and a semi-liquid sludge or "soupy" material readily forms in the bottoms of the ditches,

greatly reducing their capacity unless removed. Hyacinths and moss also grow in the water and further reduce the capacity of the ditches. It is therefore essential that regular maintenance be provided if the drainage systems are to operate efficiently. No accurate data are available on the annual cost of proper maintenance of ditches and levees, but it is certain that at least $1 per acre should be allowed for this purpose.

Pelican Lake Unit No.1. The two engines are each 80 horsepower full Diesel, type Y, made by Fairbanks-Morse and Co. They are vertical, two-cylinder engines directly connected to the pumps. The full speed is 300 revolutions per minute but this can be varied by special adjustments. The two pumps are each 42-inch Wood-screw type, with a rated capacity of 30,000 gallons per minute. The pump house is made of corrugated metal on timber frame work and is set on a concrete foundation. The total cost of the plant was $55,000. Pumping operations were started in 1925.

Fuel oil consumption during the three-year record has averaged 1.09 gallons per acre-foot pumped, and 5.26 gallons per pump-hour of operation. The average annual static lift has varied from 3.3 to 3.7 feet and the maximum lift was approximately 6.7 feet.

Pelican Lake Unit No.2. This plant is similar to Pelican Lake Unit No.1. The total cost of the plant was $51,000. Pumping operations were started in July, 1929.

Fuel oil consumption during the three-year record has averaged 1.09 gallons per acre-foot pumped and 5.39 gallons per pump-hour of operation. The average annual static lift has varied from 3.8 to 4.2 feet and the maximum lift was approximately 7.7 feet.

Figure 6 shows the record of pump operation at the two Pelican Lake plants for the year 1934. Similar charts have been prepared for the years 1933 and 1935. Copies of these may be obtained from the Bureau of Agricultural Engineering at Washington, D.C. The total annual amount of pumping, the depth from the drainage area, the rainfall, fuel oil used, and average lifts are shown for each plant. The average annual rainfall for the three years was 61.1 inches. A 13-year record at the U.S. Department of Agriculture Cane Station at Canal Point shows an average of 54.1 inches. It is hence probable that the average amount of pumping during the three year period was somewhat above normal.

An examination of the charts for these units shows that the amount of pumping depends very materially on the stage of the West Palm Beach Canal. In August, 1935, with a rainfall of 7.35 inches and a very low canal stage there was no pumping at either unit, while in October with a rainfall of 5.25 inches unit 1 pumped 4,247 acre-feet and unit 2 pumped 1,693 acre-feet. Some of this difference between the two months may be due to holding a lower water table in October but it is certain that the major factor was the higher stage in the West Palm Beach Canal.

The records for the three year period show an average annual depth of 5.33 feet of water pumped from the drainage area of Pelican Lake unit 1 and 3.70 feet from the drainage area of unit 2. The difference is due

largely to the higher water table which usually exists along the east side of unit 1 whereas unit 2, due to the low ground in the Pelican Lake farms areas, has a much lower water table along its south and west side. This comparison clearly shows the effect of the exterior water table on the amount of pumping within a drained area.

East Pahokee Unit No. 1. The two engines are each 180 horsepower full Diesel, type Y, made by Fairbanks-Morse and Co. They are vertical, three cylinder engines directly connected to the pumps. The full speed is 257 revolutions per minute. There is a speed control on each engine whereby the speed can be readily varied as desired. This is quite an advantage in adjusting the discharge of the plant to the inflow from the ditches. The two pumps are each a 54-inch Wood-screw type, with a rated capacity of 60,000 gallons per minute. The pumphouse is made of corrugated metal on steel framework and is set on a concrete foundation. The total cost of the plant was $75,000. Pumping operations were started in November, 1929.

Fuel oil consumption during the three-year record at this plant has averaged 1.02 gallons per acre-foot pumped, and 6.5 gallons per pump-hour of operation. The average annual static lift varied from 4.6 to 4.9 feet and the maximum lift was approximately 7.5 feet.

East Pahokee Unit No. 2. The equipment of this unit is similar to that of unit No. 1. The total cost of the plant was $105,000. The plant was first operated in January, 1930.

Fuel oil consumption during the three year record at this plant has averaged 1 gallon per acre-feet pumped, and 8 gallons per pump-hour of operation. The average annual static lift varied from 4.4 to 4.7 feet and the maximum lift was approximately 7.2 feet.

Figure 7 shows the record of pump operations at the two East Pahokee plants for the year 1934. Similar charts have been prepared for the years 1933 and 1935. Copies of these may be secured from the Bureau of Agricultural Engineering at Washington, D. C. The total annual amount of pumping, the depth from the drainage area, the rainfall, fuel oil used and average lift are shown for each plant. As the average annual rainfall for the three years was 60 inches, while that for a 13-year period at the U.S. Department of Agriculture Cane Station at Canal Point was 54.1 inches, it is probable that the average amount of pumping during the 3-year period was somewhat above normal.

An examination of the charts again shows that the amount of pumping depends considerably on the stages of the West Palm Beach Canal. This is particularly noticeable in comparison of the records for August and October, 1935.

During the 3-year period the average annual depth of water pumped from the drainage area of unit 1 was 2.49 feet while that pumped from unit 2 was 2.73 feet. The two units are not completely separated as a ditch at the west end of the district may carry water to either unit. However, if the two units are combined the average annual depth pumped off would be 2.64 feet.

Taken separately, unit 2 shows a little greater depth pumped than unit 1. This is doubtless due to the fact that the entire south line of unit 2 abuts on undrained land along a 9-mile levee and the seepage is therefore increased.

Occasionally during long dry spells the pumps are reversed and water is pumped into the districts to raise the water table. It usually takes a day to reverse a large pump of the Wood-screw type. Only a small amount of the total water pumped is thus used for irrigation. No irrigation water was pumped into either the Pelican Lake or East Pahokee districts during the year 1934.

Usually no very definite water elevation is held at the pump intakes. The water is often pumped down to a very low level at the intake and the pumps then stopped until the ditch again fills. It would be better practice to hold the intake level at a near constant elevation. The movement of the seepage water would then be more uniform and the average lift of the pumps would be somewhat reduced. To accomplish this, the engines of pumping plants should have variable speed controls and the ditches should be so maintained that they can deliver their designed rates of flow.

The Everglades Experiment Station Plant. The electric motor is a four speed Westinghouse, type C.S. induction model. It is rated at 4.2 to 30 horsepower depending on the speed used, and is connected to the pump by means of a set of short V-belts. The four speeds are 445, 590, 890, and 1,180 revolutions per minute. However nearly all the operation is at the third speed of 890 revolutions per minute. The pump is a 24-inch vertical turbine rated at 10,000 gallons per minute at high speed, and is so built that water can be either pumped in or out of the area served by the simple operation of four vertical slides. It was made by the Couch Manufacturing Co. and has four speeds of 217, 292, 442, and 574 revolutions per minute. The pump is started and stopped by an automatic float in the intake ditch and requires little attention during operation. The pumphouse is made of corrugated metal on steel framework and is set on a concrete foundation. The total cost of the plant was approximately $3,400. It began operating in July, 1931.

The electric power used is 3-phase, 60-cycle, 220 volt current. The cost for power was based on a charge of $4.00 per "contract" horsepower for the first 25 "contract"1/ horsepower per month for four months in each yearly period; $3.00 per "contract" horsepower for all additional "contract" horsepower per month for four months in each year; and 3 cents per kilowatt hour for all energy used per month. The annual cost of electric power during the three years of this record has averaged $4.76 per acre served and 6.2 cents per kilowatt hour used. The average period of operation has been 60 days per year. The average annual rainfall for the three years was 58.8 inches which is a little greater than an 11-year average of 58.0 inches at the Everglades Experiment Station. The average

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1/ A "contract" horsepower is the average horsepower supplied during the 15-minute period of maximum use during each 12-month period ending with the month for which the bill is rendered.

annual static lift has varied from 2.0 to 2.3 feet and the maximum lift was approximately 4 feet. The record for the three years shows an average annual depth of 8.11 feet of water pumped from the drainage area of 162 acres.

Figure 8 shows the record of pump operations at the Everglades Experiment Station plant for the year 1934. Similar charts have been prepared for the years 1933 and 1935. Copies of these may be secured from the Bureau of Agricultural Engineering at Washington, D.C. The total amount of pumping, the depth pumped from the drainage area, the kilowatt hours used, the rainfall, and the stages of the Hillsboro canal are shown for each year.

The charts for the three years clearly show the marked effect of the stages of the Hillsboro canal on the amount of pumping. In August, 1935, the rainfall was 6.54 inches and there was no pumping, while in October with a rainfall of 5.71 inches the amount pumped was 433 acre-feet. In October the Hillsboro canal averaged 3.2 feet higher than in August. This seepage inflow evidently moves principally through the porous rock beneath the soil. In ditches around some water table plots at the Experiment Station the water is held constant at 4 feet below the surface while the water table in the 100 by 220 foot plots stands about 8 inches higher. As the ditches are dug to rock it seems apparent that the seepage which supports the water table in the plots must come through the rock beneath. It has also been noted that when an excavation is carried to rock the water will bubble up through the voids in numerous places. The 1934 chart (fig. 9) shows a depth of 8.7 feet pumped off, 0.5 foot pumped on, and a rainfall of 5.2 feet for the year. Evaporation tanks at the Experiment Station indicte that the annual loss by evaporation and transpiration from the drainage area will approximate 4 feet. These data indicate that the seepage inflow during the year was about 7 feet. The 162 acres has a frontage of over a mile along the Hillsboro canal.

The records at the Experiment Station indicate that for small drainage areas planted to truck crops the pumping plant should have a capacity of at least 3 inches in 24 hours over the area served. With this capacity crops will be damaged every few years by excessive storms. An 11-year record at the Experiment Station (see table 7) shows 18 rains of 3 inches or more in 24 hours but 12 of these fell during the four wet months from June to September when little farming is done. Possibly a greater capacity would prove economical, depending on the kind and value of the crops grown. A pumping capacity of 1 inch appears to be satisfactory for large drainage areas planted to sugar cane.

Fixed and Operating Costs of Pumping

The cost of pumping of the drainage districts on the peat lands around Lake Okeechobee is moderate. The static lifts are low averaging around 4.5 feet; the total time of pumping if all pumps in a plant were operated at the same time, would average less than 60 days per year; and the land served will produce two to three truck crops per year. The land in sugar cane produces one crop per year. The cost of fuel oil for the large plants is approximately 6.5 cents per gallon. The records of the four large pumping plants previously considered indicate that the average annual depth of pumping from districts (with a 1-inch run-off) is less than 4 feet. On the basis of 1 gallon of fuel per acre-foot the average cost of fuel oil would approximate

25 cents per acre. The fixed charges and maintenance constitute by far the greater part of the total costs. However, it should be remembered that the total cost of operating a drainage district also includes the cost of maintenance of ditches and levees, which alone when properly done constitutes a large item. It should also be noted that if the rate of run-off from the area served is increased the cost of pumping, especially the fixed charges, will increase at somewhat less than the same proportion. The immediate operating costs will depend somewhat on the size of the area served and the seepage conditions outside the levees. The plants studied in this report are especially well constructed and the mechanism is of a type which will render long service. The concrete foundations were carried to rock and were quite expensive.

The term "fixed charges" as used in this report includes the annual interest on the capital invested and the annual depreciation charge. The interest on capital invested in the plants is figured at 6 percent. The depreciation charge has been computed by the sinking fund method and the annual charge is such an amount that, invested at 4 percent compound interest, the sum of the payments and the interest will equal the cost of building and equipment at the end of its estimated life.

As both the building and equipment in the plants studied are of a very durable type, the life of the entire plant has been estimated at 20 years. One of the plants has been in operation for over 10 years. The Wood-screw type of pumps have all moving parts above the water in the suction and discharge bays and the heavy duty diesel engines are of a type that has been in use nearly 20 years in other fields. The pumphouses are subject to hurricane damage but the repairs usually consist of replacing some of the corrugated metal sheeting. Table 10 shows the installation cost and fixed charges for each plant computed on the above basis.

The costs of fuel oil or electricity, lubricating oil and labor of attendance are shown in table 11. These items are shown as a total for each plant and as unit costs per acre served and per acre-foot pumped. The period of operation is expressed in plant-days. As the oil engine plants have two or more pumps and all or part of the units may be in operation at a particular time, the total days on which pumping was done was greater than the plant-days shown. The plant-days were determined by reducing the total pump-hours to 24-hour days and dividing the result by the number of pumps.

The acre-feet pumped is the total for both drainage and irrigation. The amounts pumped for each purpose are shown on the charts. Only a minor amount of water is pumped for irrigation. At the Everglades Experiment Station plant a little water was run either in or out by gravity. It is probable that these amounts were about equal. A very small amount of pumping was done by a 25 horsepower semi-diesel engine but the power thus furnished was estimated in kilowatt hours and added to the meter readings for the Everglades Experiment Station plant.

The labor costs at the oil engine plants include the wages of the attendant and help used in cleaning the screens and also the salary of the superintendent in charge of the four plants. As the labor records in-

Table 10.- Fixed Charges of Pumping Plants

Plant	Cost: Building	Cost: Engines and pumps	Cost: Total	Depreciation	Interest at six percent	Total fixed charges
Pelican Lake Unit No.1	$24,250	$30,750	$55,000	$1,847	$3,300	$5,147
Pelican Lake Unit No.2	20,250	30,750	51,000	1,713	3,060	4,773
East Pahokee Unit No.1	32,000	43,000	75,000	2,519	4,500	7,019
East Pahokee Unit No.2	40,000	65,000	105,000	3,526	6,300	9,826
Everglades Experiment Station	1,900	1,500	3,400	114	204	318

Table 11.- Costs of Fuel Oil, Electricity, Lubricating Oil, and Labor at Pumping Plants

Plant	Year	Size[1/] engine or motors	Area served	Period of operation	Water pumped	Cost: Fuel oil or electricity	Cost: Lubricating oil	Cost: Labor	Cost: Total	Cost: Per acre served	Cost: Per acre-feet pumped
		H.P.	Acres	Plant Days	Acre-feet	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
Pelican Lake Unit No.1	(1933	160	3,379	82.8	19,181	1,384	298	1,510	3,192	0.94	0.17
	(1934	160	3,379	103.4	23,764	1,710	373	1,910	3,993	1.18	.17
	(1935	160	3,379	48.6	11,105	764	175	1,250	2,189	.65	.20
Pelican Lake Unit No.2	(1933	160	2,853	41.6	9,858	718	159	1,062	1,939	.68	.20
	(1934	160	2,853	61.5	14,287	1,037	235	1,315	2,587	.91	.18
	(1935	160	2,853	30.6	7,488	492	117	1,143	1,752	.61	.23
East Pahokee Unit No.1	(1933	360	5,798	48.2	15,607	1,070	222	971	2,263	.39	.14
	(1934	360	5,798	55.6	16,588	1,138	256	1,160	2,554	.44	.15
	(1935	360	5,798	37.4	11,210	666	172	930	1,768	.30	.16
East Pahokee Unit No.2	(1933	540	9,478	49.7	28,609	1,970	277	1,212	3,459	.36	.12
	(1934	540	9,478	54.6	30,271	2,086	305	1,430	3,821	.40	.13
	(1935	540	9,478	35.3	21,385	1,184	197	1,101	2,482	.26	.12
Everglades Experiment Station	(1933	30	162	72.4	1,670	785	---	75	860	5.31	.51
	(1934	30	162	55.8	1,499	780	---	75	855	5.28	.57
	(1935	30	162	51.0	1,349	750	---	75	825	5.09	.61

1/ Both units of the Pelican Lake District have two engines of 80 horsepower each.
Unit No.1 of the East Pahokee District has two engines of 180 horsepower each.
Unit No.2 of the East Pahokee District has three engines of 180 horsepower each.

cluded the time spent by the men on repairs, the superintendent's estimate of 80 percent as chargeable to operations was used. The Experiment Station plant requires no regular attendant so the labor item was estimated.

The two Pelican Lake plants are quite similar but unit No. 1 pumps much more water than unit No. 2 due to seepage conditions. The costs per acre served are therefore higher for unit No. 1 and the costs per acre-foot pumped are lower. The two East Pahokee plants are larger and much more efficient than those of Pelican Lake and the unit costs are therefore lower.

The annual maintenance costs as shown in table 12 have been estimated at 1 percent of the total investment in the plants. It is probable that $1 per horsepower per year would easily cover the engine repairs. The pumps and buildings require very little maintenance. The records available are not sufficient to determine this cost but 1 percent is believed to be ample. No insurance is carried on the plants and no taxes are charged against the property.

The fixed charges for the four oil engine plants average approximately two-thirds of the total cost of pumping and that for the one electric plant amounts to approximately one-fourth of the total cost. The cost per acre served for the Pelican Lake plants averages $2.60 while that for the East Pahokee plants is $1.60. This difference is due principally to the greater investment per acre in the Pelican Lake plants but the greater amount of water pumped per acre and the lesser efficiency of the Pelican Lake plants accounts for some of the difference. For the four oil engine plants the average cost per acre-foot pumped was 63 cents and the average cost per acre-foot lifted 1 foot was 15 cents. The Experiment Station plant shows an average cost per acre-foot pumped of 80 cents, and an average cost of 36 cents per acre-foot lifted 1 foot.

The Experiment Station plant provides for a discharge per acre which is approximately three times as large as that of the oil plants and other conditions vary so widely that no fair comparison can be made between the costs of electric and oil power on the basis of the figures shown in table 12. The cost of electric power is largely dependent on the load factor or percent of time that the plant is in use. The convenience of electric power could be had at a fairly low cost if a plant were composed of two or three pumping units--an electric unit with a capacity of 1/3- to 1/2-inch of run-off and one or two oil engine units to handle additional water as needed. The seepage and light rains would keep the electric unit in operation much of the time and in the dry months this unit would have sufficient capacity to supply the needed irrigation water. The economical capacity of the several units would depend on the area drained, the seepage conditions and the kind of crops grown.

Special Tests of Oil Plants.

Overall efficiency tests were made at each of the oil engine plants in 1935; the discharge of the pumps was measured with a Pitot tube and the fuel consumed in an hour's time was carefully weighed. The static lifts

Table 12.- Total Operating Costs Including Fixed Charges

Plant	Year	Average static life	Water pumped	Area served	Fixed charges	Maintenance	Oils and labor	Costs for year: Total amount	Costs for year: Per acre served	Costs for year: Per acre-ft. pumped	Costs for year: Per acre-ft. lifted 1 foot
		Feet	Acre-feet	Acres	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
Pelican Lake	(1933	3.3	19,181	3,379	5,147	550	3,192	8,889	2.63	0.46	0.14
Unit No.1	(1934	3.3	23,764	3,379	5,147	550	3,993	9,690	2.87	.41	.12
	(1935	3.7	11,105	3,379	5,147	550	2,189	7,886	2.33	.71	.19
Pelican Lake	(1933	4.2	9,858	2,853	4,773	510	1,939	7,222	2.53	.73	.17
Unit No.2	(1934	4.3	14,287	2,853	4,773	510	2,587	7,870	2.76	.55	.13
	(1935	3.8	7,488	2,853	4,773	510	1,752	7,035	2.47	.94	.25
East Pahokee	(1933	4.6	15,607	5,798	7,019	750	2,263	10,032	1.73	.64	.14
Unit No.1	(1934	4.7	16,588	5,798	7,019	750	2,554	10,323	1.78	.62	.13
	(1935	4.9	11,210	5,798	7,019	750	1,768	9,537	1.64	.85	.17
East Pahokee	(1933	4.7	28,609	9,478	9,826	1,050	3,459	14,335	1.51	.50	.11
Unit No.2	(1934	4.7	30,271	9,478	9,826	1,050	3,821	14,697	1.55	.49	.10
	(1935	4.4	21,385	9,478	9,826	1,050	2,482	13,358	1.41	.62	.14
Everglades	(1933	2.0	1,670	162	318	34	860	1,212	7.48	.73	.36
Experiment	(1934	2.3	1,499	162	318	34	855	1,207	7.45	.81	.35
Station	(1935	2.3	1,349	162	318	34	825	1,177	7.26	.87	.38

are the difference in readings of the gages just outside of the screens at either end of the plant. The useful work done by the plant, or water horsepower, is based on the pump discharge and static lift. The emergency output of engine is estimated on the basis of 0.50 pound of fuel oil per brake horsepower. The overall efficiency is the ratio of the water horsepower hours to the indicated horsepower hours or energy used in the engine. The mechanical efficiency or ratio of the brake horsepower to the indicated horsepower is estimated as 80 percent. The term "plant" in table 13, refers to a complete pump and engine unit. Each plant has either two or three such units. It is evident that the East Pahokee plants are much more efficient than the Pelican Lake plants. The East Pahokee pumps are of larger size and probably of more recent design. Efficiencies based on fuel consumption and brake horsepower are necessarily only approximate.

Table 13.- Efficiency Tests of Oil Engine Plants

Plant	Pump No.	Speed per minute	Static lift	Discharge of pump per minute	Work by plant	Fuel oil used per hour	Energy output of engine	Overall efficiency of plant
		Revolutions	Feet	Pounds	H.p.	Pounds	Brake h.p.	Percent
Pelican Lake								
Unit No.1	1	276	4.25	227,600	29.3	37.4	74.9	31.
" " 1	2	270	4.72	201,300	28.8	34.5	69.0	33.
" " 2	1	272	3.22	232,100	22.6	30.8	61.6	29.
" " 2	1	269	5.77	182,700	32.0	56.4	72.9	35.
" " 2	2	290	5.95	227,600	41.1	46.8	93.6	35.
" " 2	2	275	3.27	234,300	23.2	31.2	62.4	30.
Pahokee								
Unit No.1	1	250	5.80	441,500	77.6	73.7	147.5	42.
" " 1	1	227	6.15	391,500	72.9	66.1	132.3	44
" " 1	1	202	5.96	301,800	54.6	54.0	108.0	40.
" " 1	1	177	5.96	240,000	43.4	41.4	82.8	42.
" " 1	2	248	5.14	457,000	71.2	70.5	141.0	40.
" " 1	2	226	5.16	395,100	61.8	57.2	114.5	43.
" " 2	1	257	4.99	483,500	73.2	75.5	151.0	39.
" " 2	1	227	4.91	418,200	62.3	57.2	114.5	44
" " 2	1	200	4.94	356,000	53.3	46.1	92.2	46.
" " 2	1	175	5.16	279,200	43.7	38.6	77.3	45.
" " 2	1	150	5.26	148,600	23.7	29.1	58.2	33.
" " 2	3	256	5.35	488,000	79.2	71.3	142.6	44.
" " 2	3	256	6.10	480,000	88.8	79.0	158.0	45.
" " 2	3	226	6.12	401,100	74.4	63.1	126.2	47.
" " 2	3	200	6.00	336,500	61.3	47.5	95.0	52.1/
" " 2	3	176	6.02	263,500	43.1	39.2	78.4	49.

1/ Results probably too high.

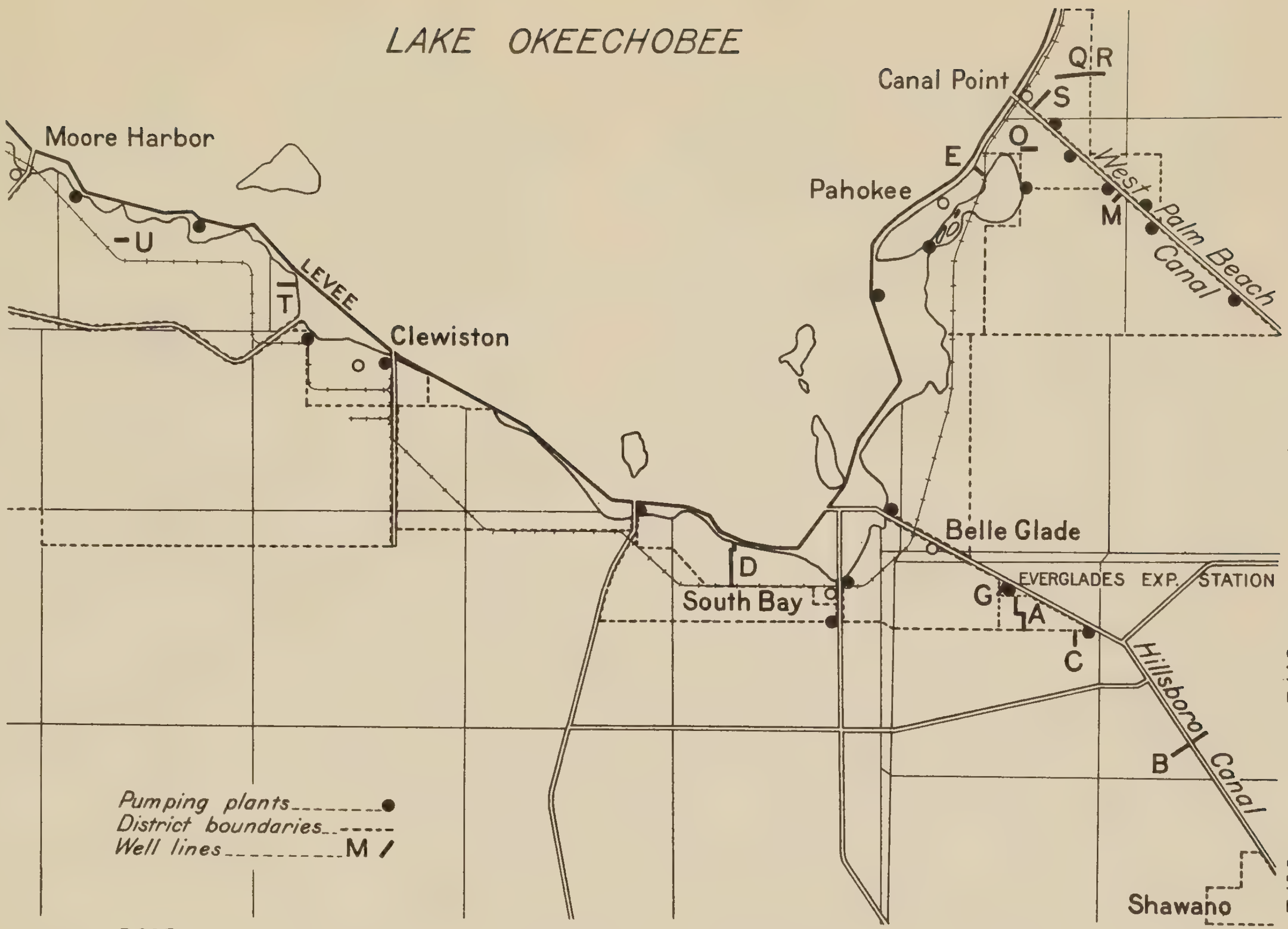

Figure I.— Location of pumping plants

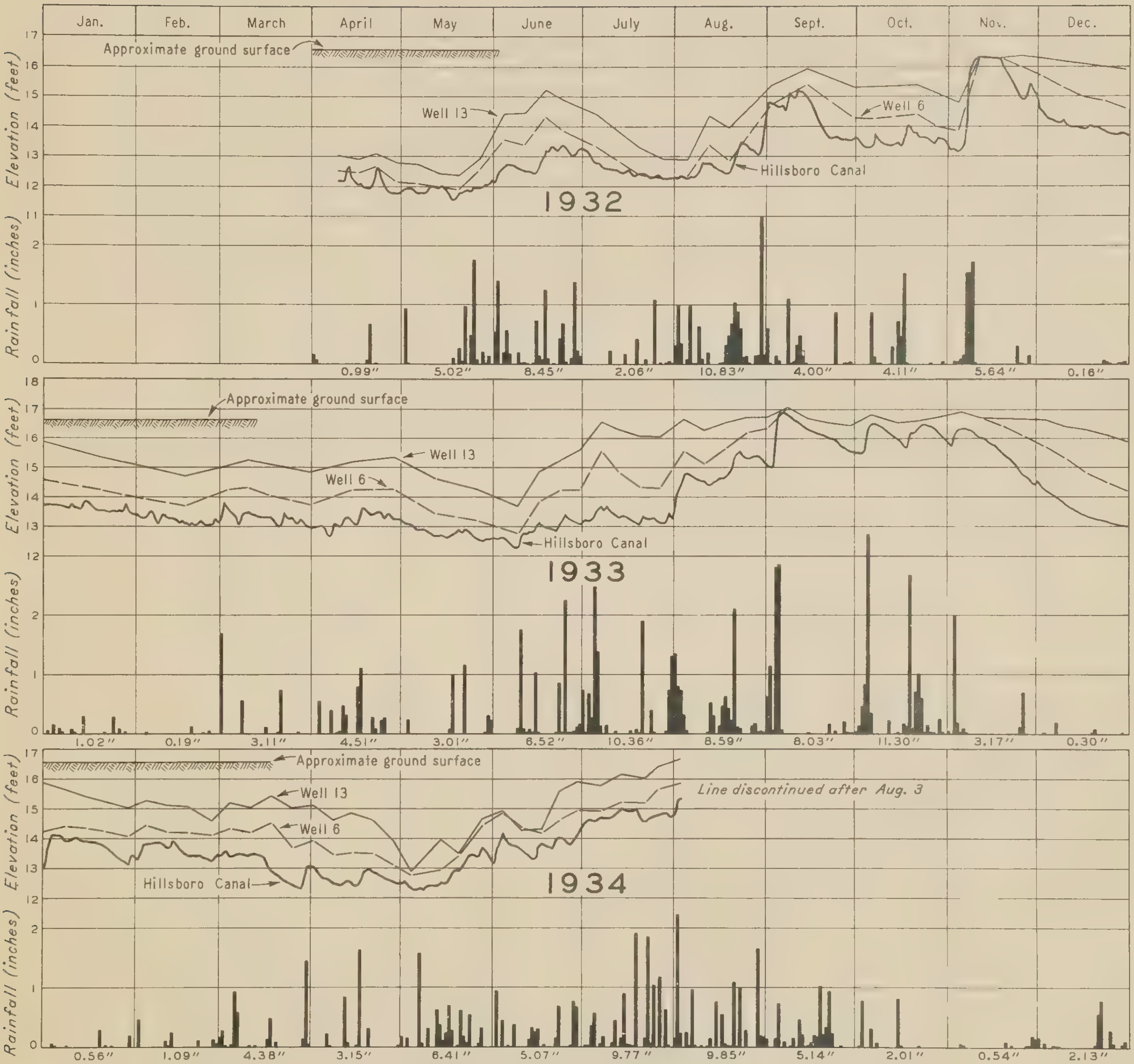

Figure 2,A.—Hydrographs of wells 6 and 13, line B, and Hillsboro Canal; rainfall at Shawano

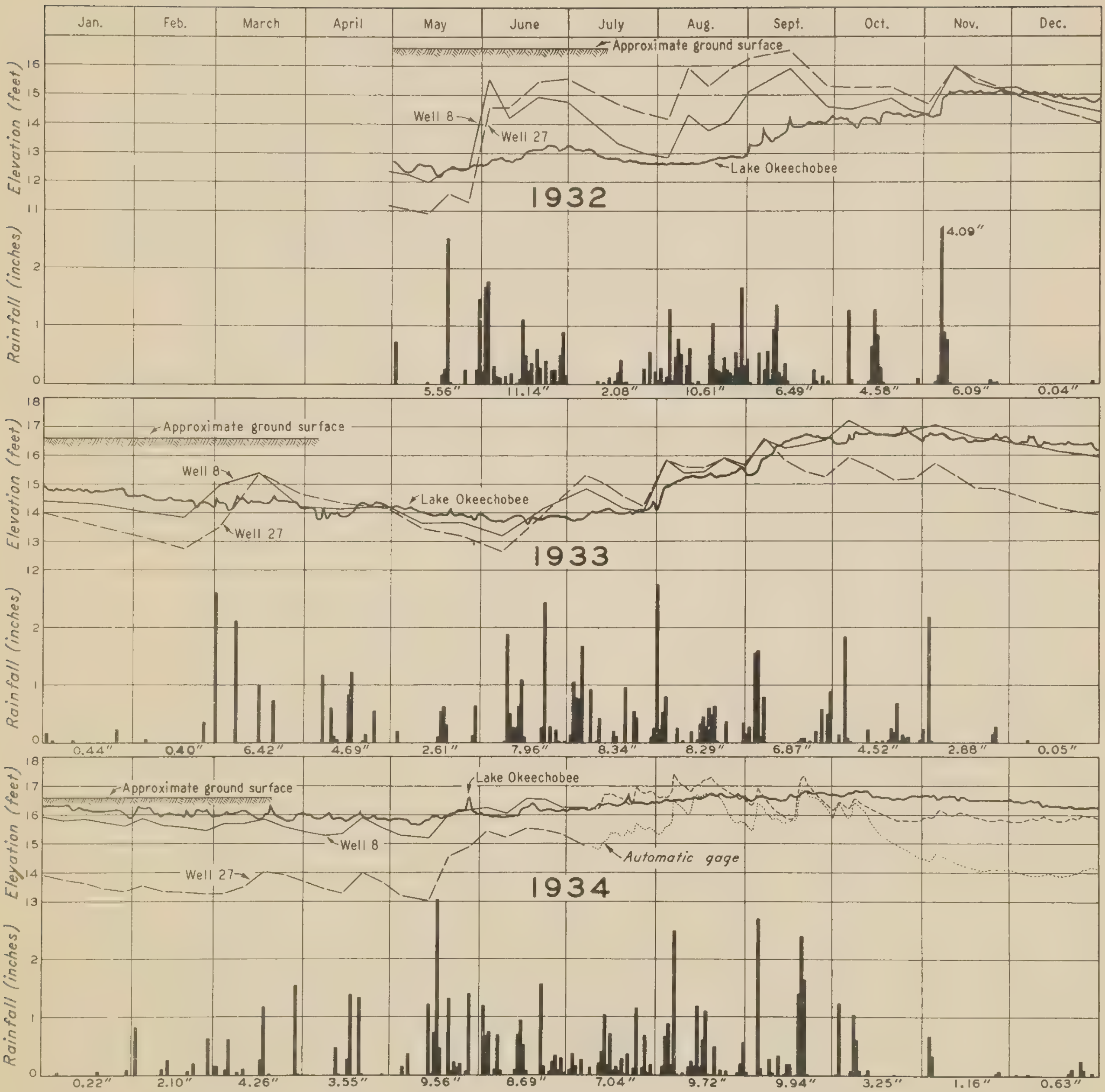

Figure 3, A.—Hydrographs of wells 8 and 27, line D, and Lake Okeechobee; rainfall near line D

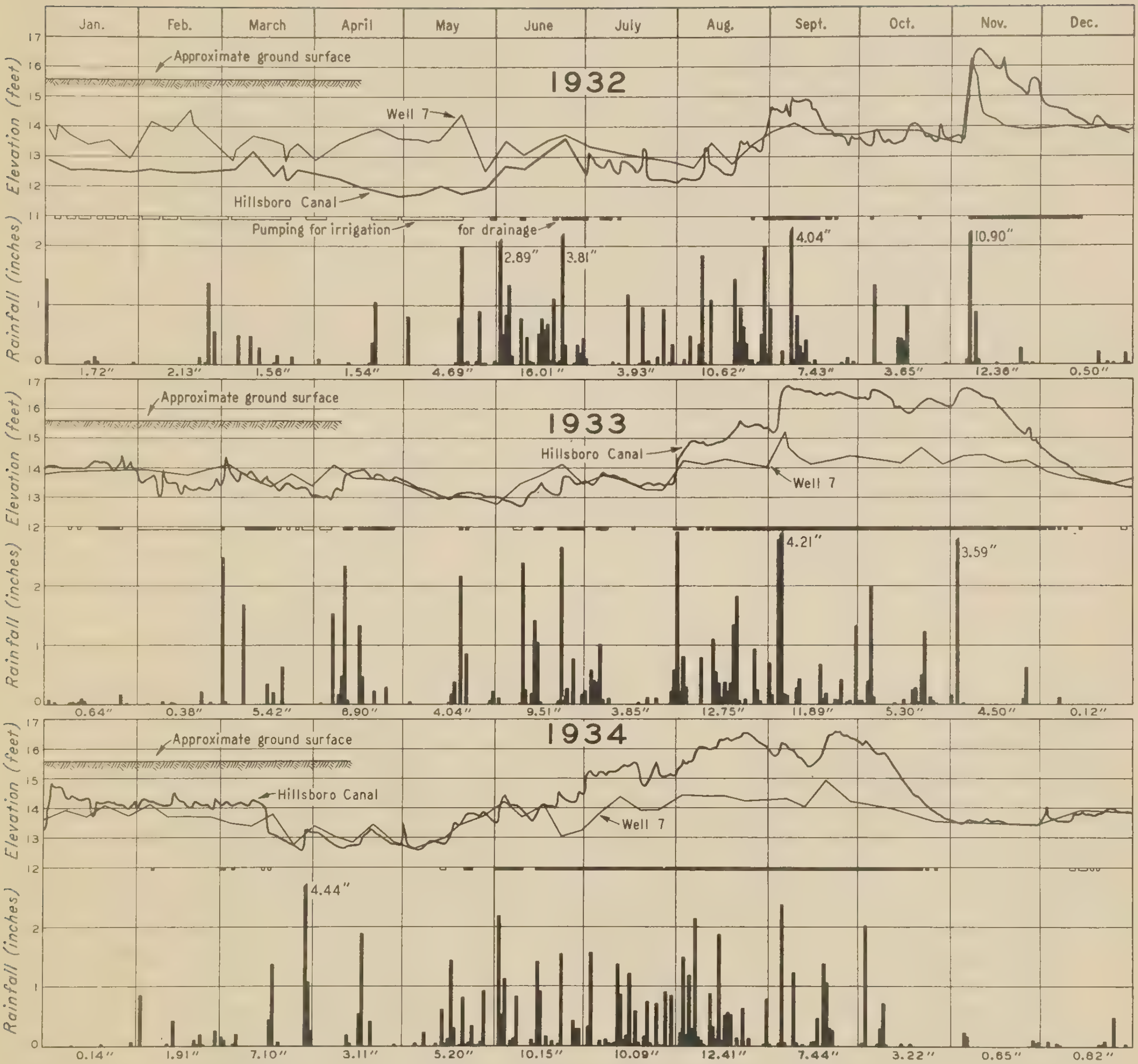

Figure 4,A.— Hydrographs of well 7, line G, and Hillsboro Canal; rainfall near line G

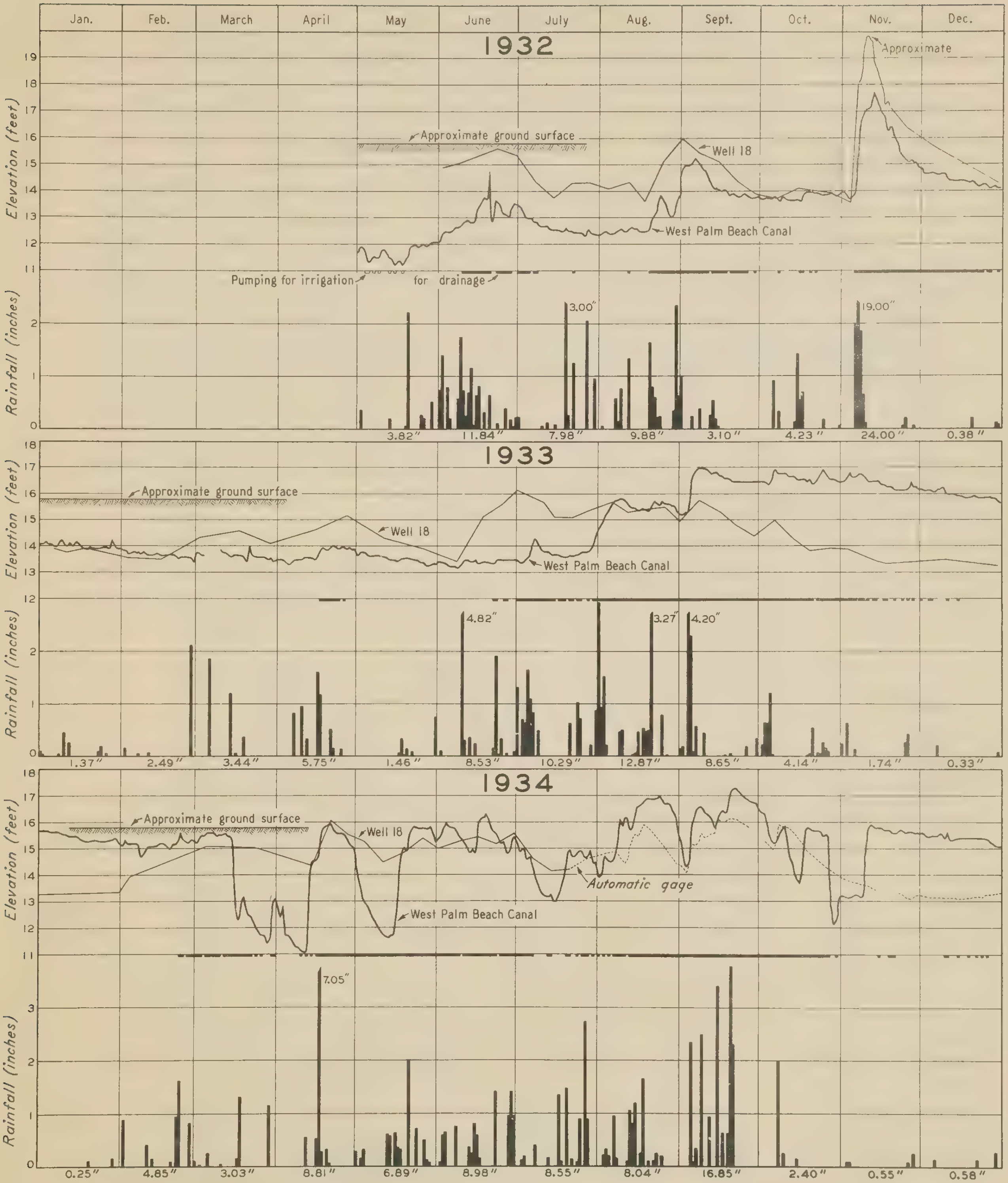

Figure 5,A.—Hydrographs of well 18, line S, and West Palm Beach Canal; rainfall at Azucar; days on which pumps operated

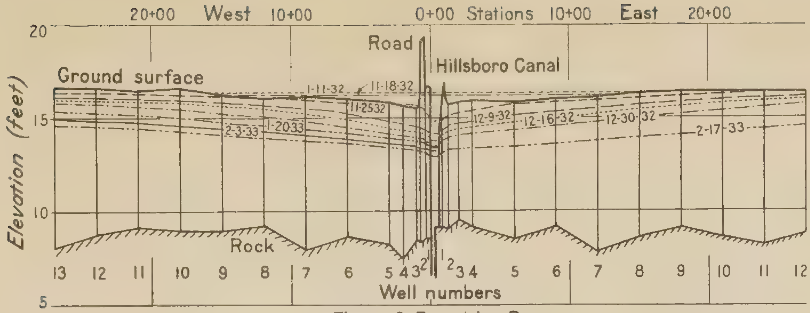

Figure 2, B. — Line B

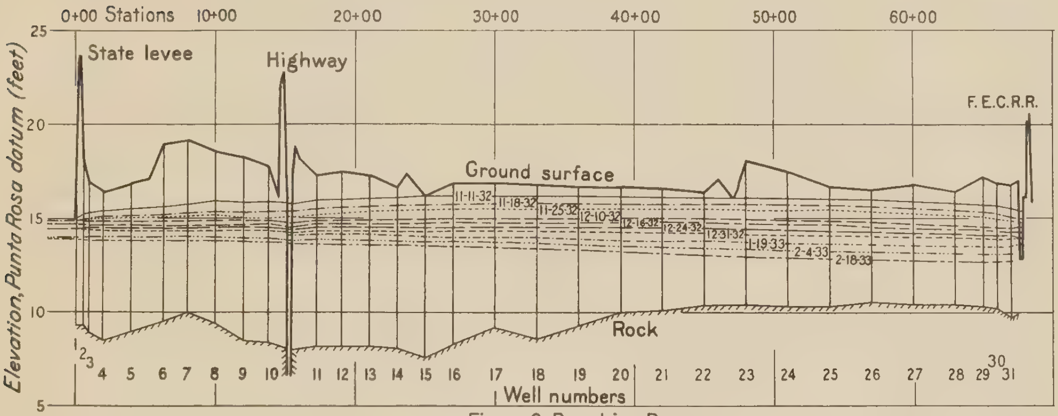

Figure 3, B. — Line D

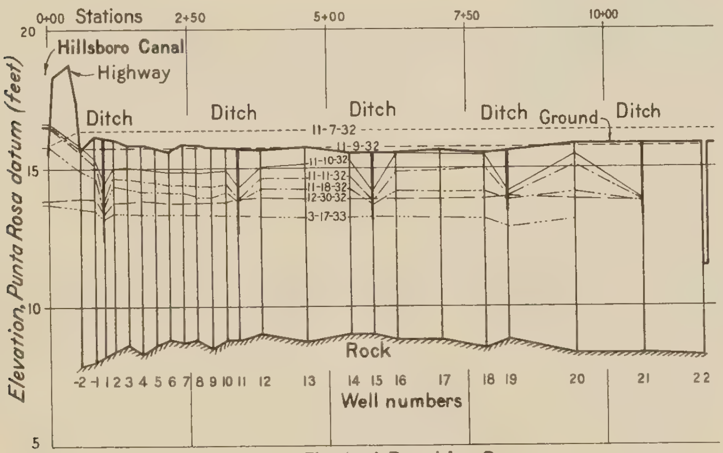

Figure 4, B. — Line G

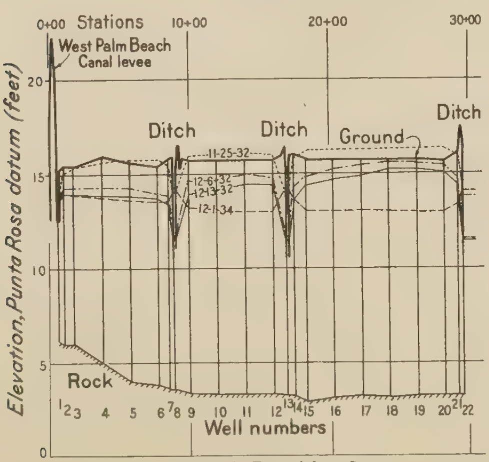

Figure 5, B. — Line S

TYPICAL GROUND-WATER PROFILES

RECORD OF PUMP OPERATION AT PELICAN LAKE DRAINAGE DISTRICT, FLA. 1934

Total water pumped for drainage	Unit No. 1	23,764.2 ac. ft.	7.03 ft. on 3,379 acres
Total water pumped for drainage	Unit No. 2	14,287.2 ac. ft.	5.01 ft. on 2,853 acres
Total rainfall (both units)		69.78 inches	5.82 ft.
Total fuel oil used	Unit No. 1	26,300 gallons	
Total fuel oil used	Unit No. 2	15,985 gallons	
Average lift of pumps	Unit No. 1	3.3 feet	
Average lift of pumps	Unit No. 2	4.3 feet	

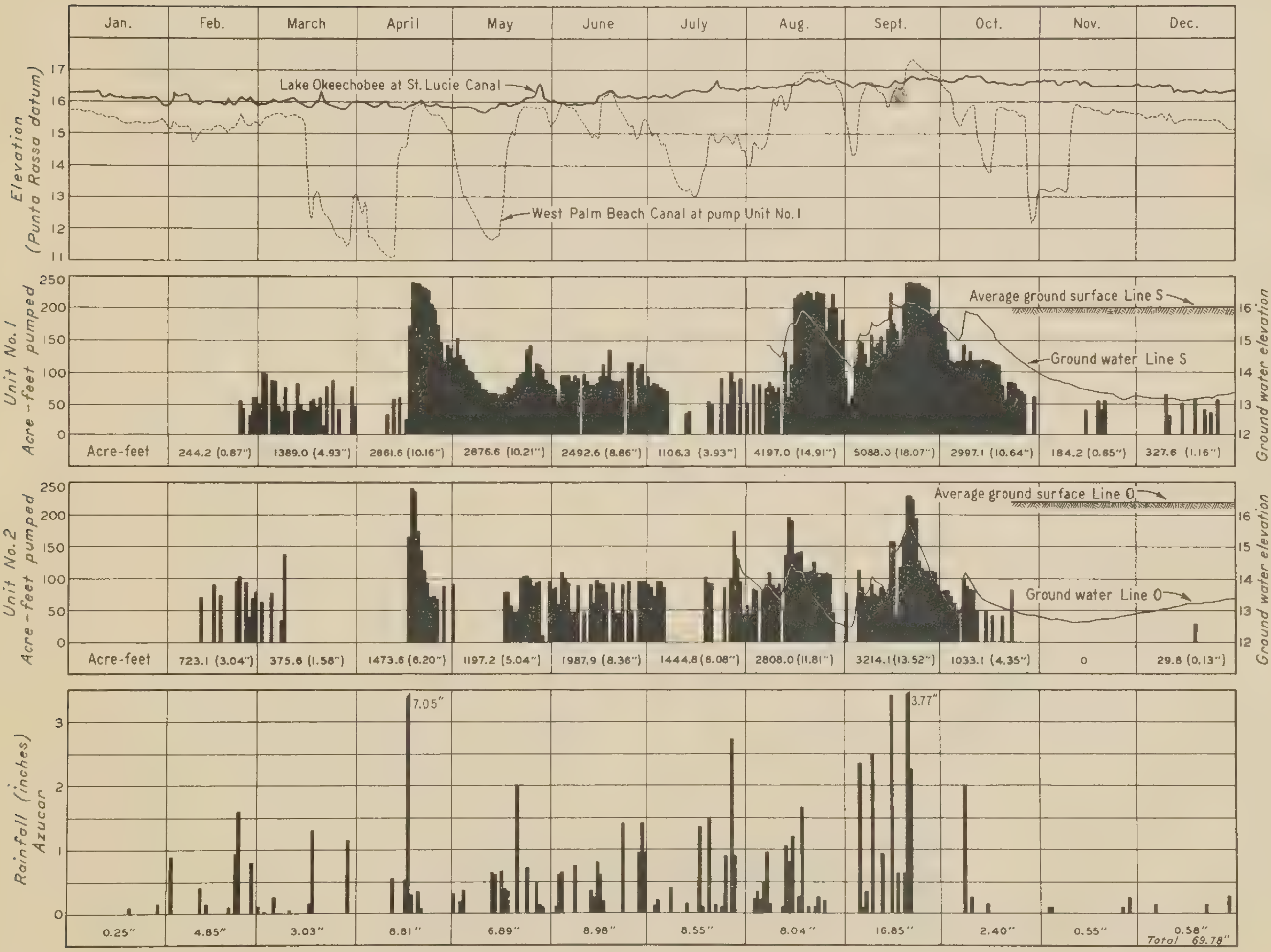

Figure 6

RECORD OF PUMP OPERATION AT EAST PAHOKEE DRAINAGE DISTRICT, FLA. 1934

Total water pumped for drainage	Unit No. 1	16,588.0 ac. ft.	2.86 ft. on 5,798 acres
Total water pumped for drainage	Unit No. 2	30,270.8 ac. ft.	3.20 ft. on 9,478 acres
Total rainfall (both units)		66.20 inches	5.52 ft.
Total fuel oil used	Unit No. 1	17,500 gallons	
Total fuel oil used	Unit No. 2	32,087 gallons	
Average lift of pumps	Unit No. 1	4.7 feet	
Average lift of pumps	Unit No. 2	4.7 feet	

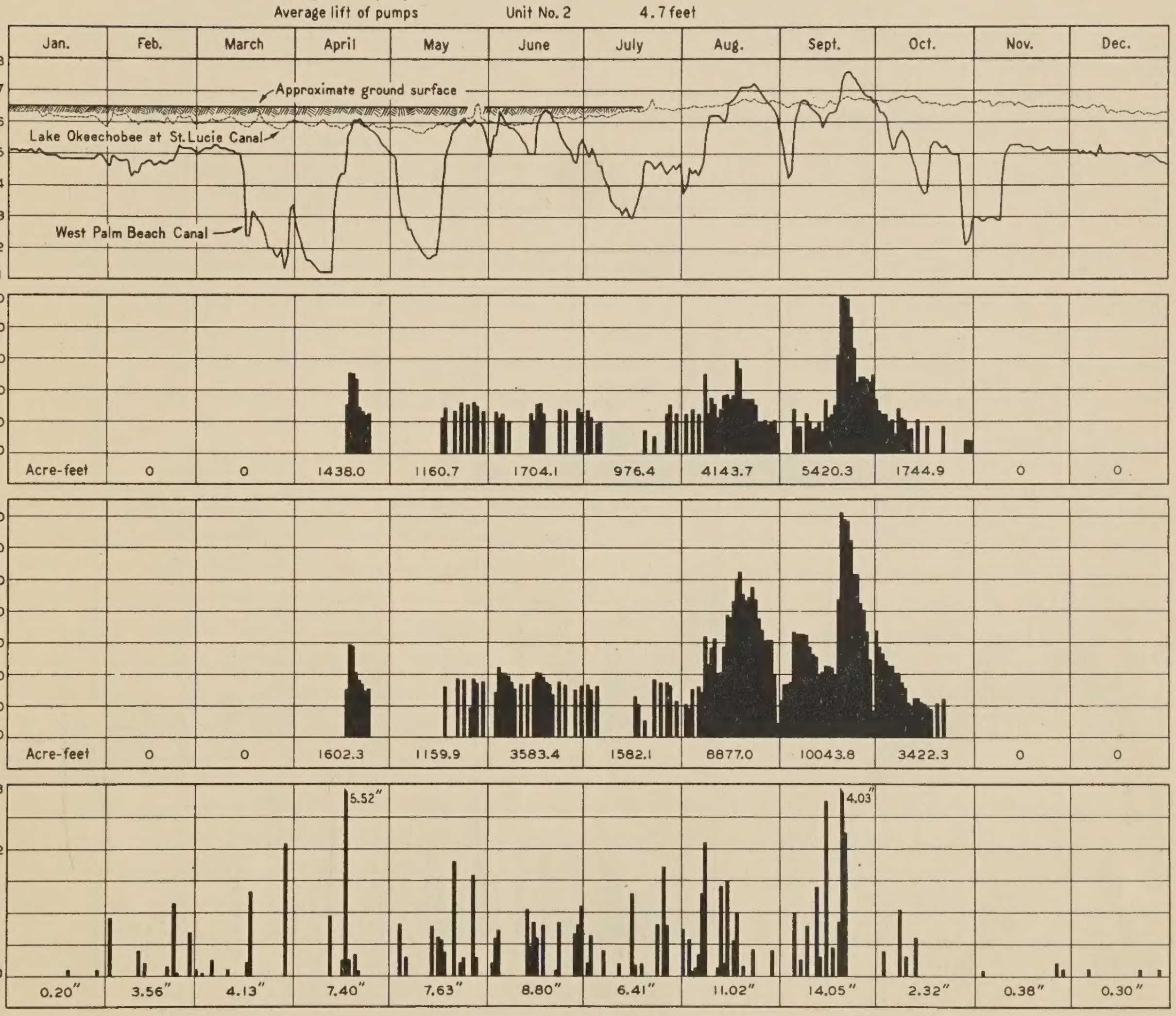

Figure 7

RECORD OF PUMP OPERATION AT EVERGLADES EXPERIMENT STATION, FLA. 1934

Total water pumped for drainage	1,411.1 ac. ft.	8.71 ft. on 162 acres
Total water pumped for irrigation	87.7 ac. ft.	0.54 ft. on 162 acres
Total time of pumping	1,338 hours	55.8 days
Total energy used	12,665 kw.-hr.	
Total cost of electric power	$780.	$4.82 per acre
Average lift of pump	2.32 feet	

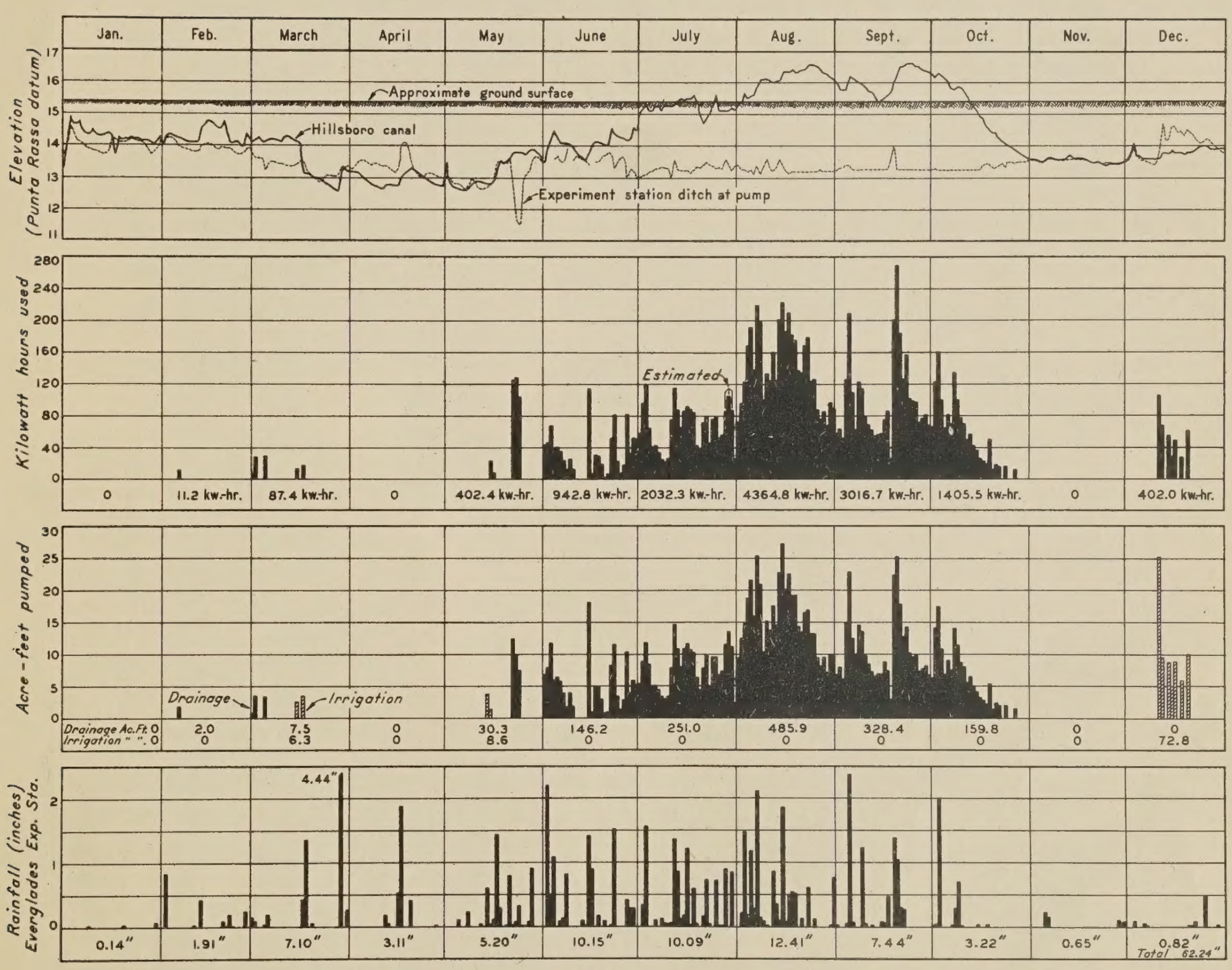

Figure 8